ENGINEERING

An Illustrated Weekly Journal

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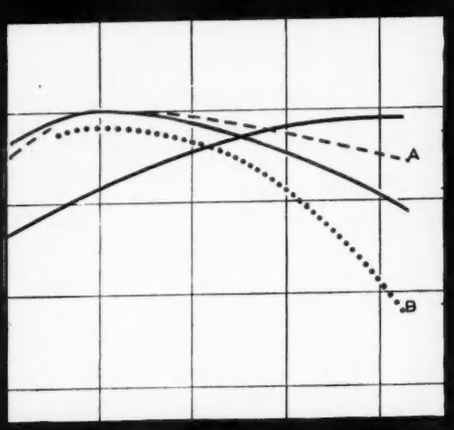

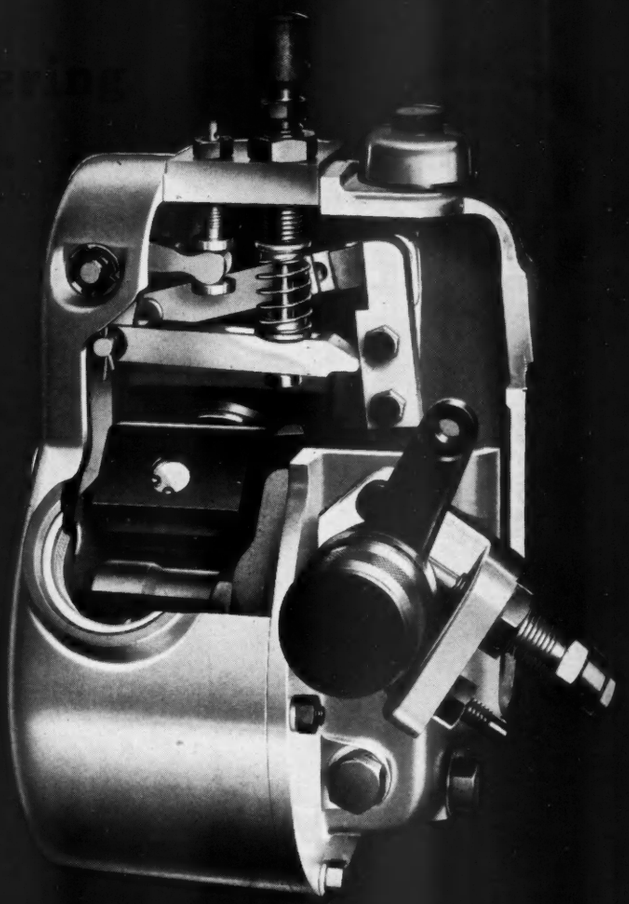

C.A.V. LIMITED

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An Illustrated Weekly Journal

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STRANGER THAN FICTION

THERE is no doubt that space-flight has captured the imagination of the public during the past few years. Science fiction, particularly of the interplanetary variety, sells to the millions instead of to the handful of "fans" in pre-war times. Here we have a unique situation and one worthy of deeper study. No other scientific or technical development has caused such a torrent of popular literature (both fiction and non-fiction) in advance of its accomplishment. To some extent, at least, it is a case of fiction generating fact; many of the more enthusiastic proponents of space-flight now earning their living on guided-missile development and similar activities were weaned on pre-war science fiction.

It is not surprising then to find that a large proportion of the engineers and scientists attending the annual congresses of the International Astronautical Federation are science-fiction addicts. This year's Congress, the seventh, is to take place in Rome next week. Although some of the papers to be presented are fittingly futuristic in tone, many of them will deal with more immediate problems such as the development of rocket motors and the design of small artificial satellites. Even the latter topic would have been considered of dubious practicality by serious engineering journals a scant few years ago, although the U.S. Government's active participation in such work now gives it a cloak of respectability.

Lack of evidence to the contrary leads one to presume that the Americans are further advanced than most other nations in the missile field, and the most likely to be the first to achieve space-flight. The story of their remarkable advances was told last Saturday by Mr. F. C. Durant to the members of the British Interplanetary Society in London. Mr. Durant is President of the International Astronautical Federation and a past-president of the American Rocket Society. In common with many other technical enthusiasts for space-flight he has a long background of guided-missile experience, having been director of engineering at the Naval Rocket Test Station.

At the end of the second World War, Mr. Durant said, the United States had virtually no guided-missile industry: to-day it is a "billion-dollar business." Germany at the end of the war was ten years ahead of the Allies in guided missiles, and had dozens of designs projected and in various stages of development. Although tons of reports were captured, together with a large number of specimens of missiles, the German experience was not adequately assimilated. By 1947, there were indeed 15 guided-missile projects under way, but sights had in many cases been set too high, and many of the projects (such as Meteor, Hermes and Loki) were not brought to a successful conclusion. Some of the requirements for these early projects had been greatly modified as a result of experience, and at present six of them are actually in service with the armed forces. These are the Sparrow (air to air), Nike, Terrier (both ground to air), Corporal, Matador and Regulus (all ground to ground). It is noteworthy that Matador and Regulus are both propelled by turbo-jet and will be the first to become obsolete. In the more recent designs for long-range missiles the turbo-jet is replaced by the ram-jet or rocket. At present there are between 30 and 35 missile projects in the United States.

During the past two or three years, two new categories of missile have come into being, the intermediate-range ballistic missile (I.R.B.M.), having a range of the order of 1,000 miles, and the inter-continental ballistic missile (I.C.B.M.) with a range of perhaps 5,000 miles. It is known that two I.R.B.M. contracts have been placed (the Thor and one so far nameless) and two for I.C.B.M's (Atlas and Titan). The tremendous advances in potential range during the past few years can be judged from the fact that the longest range ballistic missile previously announced was the Redstone with a range of a few hundred miles only.

Although performance figures and weights for these long-range missiles have not been released, it is clear from the details of the three-stage rocket to be used in launching the instrument-carrying artificial satellites that the performance of the rocket motors has not been radically improved. It can thus be inferred that the percentage of structure weight must have been drastically reduced. Mr. Durant considered the artificial satellite to be the key to space-flight. Those under present construction are to be highly polished magnesium spheres 20 in. in diameter. They will carry only 10–12 lb. of instruments. Undoubtedly animals will be sent up before long to determine their reactions to the various biological hazards such as weightlessness and primary cosmic radiation. Such experiments will precede a man-carrying satellite, which he foresees in about the next ten years. Twenty-five years should bring the circum-lunar trip, and a lunar landing would be possible before the end of the century. Many of the papers at this years' and succeeding years' International Astronautical Congresses will help to bring these prophecies to fruition. Development during the next few years may further compress Mr. Durant's time scale.

Plain Words

A curious conclusion may be drawn from some figures for expenditure on research and development recently published by the Department of Scientific and Industrial Research. The survey is not yet complete but preliminary results were given in a paper presented to the British Association on September 4 by Mr. E. Rudd, who compared British and United States expenditure in this field.

Britain appears to have spent in the financial year April, 1955, to March, 1956, roughly £325 million; of this, £185 million was the cost of research carried out in private industry—aircraft, electrical engineering and chemical firms contributing the major part. These three industries spent about three-quarters of the total. Of the sum spent in private industry a very considerable proportion, probably well over £100 million, has been supplied by Government departments for research contracts or otherwise. This means a comparatively small figure was spent by industry itself. Moreover, when it is noted that I.C.I. devotes well over £7 million per annum to research and development, and that G.E.C. has been spending £½ million each year on atomic energy development alone—without Government assistance—it becomes clear that other firms and industries provide very little. A corresponding figure for American industry, although in this case reference is made to 1953, is £1,320 million, taking the rate of exchange as 2·80 dols. to the pound. The same industries as in Britain were responsible for the greater proportion. In America, however, they spent half the total compared with the three-quarters in Britain. In terms of manpower, industry in the United States employs about six times as many graduates on research and development as does industry in Britain.

These figures appear to reflect most unkindly on Britain, and British industry in particular, though on a basis of national incomes they may not be so serious. Nevertheless, the small proportion of total expenditure on research provided by private industry needs to be examined. First, we must understand the purpose of industry. Certainly economy of production is an important consideration, and industry can only economically carry out research if this research contributes to its immediate or not too far distant interests. Pure research which may yield results in perhaps 50 years' time is not likely to be undertaken by industry. If, however, it is considered to be in the national interest for such research to be carried out, then either it must be undertaken by Government institutions; or the Government must apply economic and legislative measures to make such research consistent with industry's own interests. Economic pressures of this kind have proved notoriously successful in the motor-car industry.

Lord Halsbury has suggested that the sentence "We don't need a research laboratory" should be considered with the emphasis placed on each word in turn. The conclusion may be in fact that a particular firm does not need a *research* laboratory or a research *laboratory*. Research is only the function of industry if it is necessary in order to prevent that industry from running down, and in that case the expenditure involved must be distributed over the products in current or future production. It has been suggested that the best place for pure research is in the universities; for research which is intermediate between pure and utilitarian in character the research organisations are ideal; and only that research which is of immediate value to industrial firms should be carried out by industry itself. There are of course exceptions—large firms with extensive resources devote part of them at least to fundamental research.

It is, however, the problem of communication between these various research organs that is rather more serious. Discoveries made by firms are frequently not, for commercial reasons, communicated to their industry's research association, and the results of pure and even engineering research often take many years to be applied. Mr. James Callaghan is not the only one to have said "American industrialists are applying our research faster than we are." Thus if we are to maintain our place in the world we must first establish efficient lines of communication between the various research organs. Then, but only then, should we devote more money to the research itself. Otherwise it would be wasted.

* * *

BRITISH ASSOCIATION

Many of the non-engineering papers delivered to the British Association are of engineering significance. Several were treated in Weekly Survey notes last week, and two more are reported below. Plain Words refers to a paper on research expenditure. Engineering Section papers will be found elsewhere in this issue.

Anti-Oxidants

Many kinds of chemical molecules are subject to attack by molecular oxygen and in some products this attack represents a considerable disadvantage; this is true, for example, of oil, rubber and foodstuffs. The function of anti-oxidants is to inhibit such reactions and lend stability to the substance concerned. Examples of oxidising reactions are the oxidation of inorganic salts, the oxidation of organic molecules such as hydrocarbons, alcohols, phenols and others, and biochemical oxidations necessary to vital processes. The ease and extent of such reactions depends upon the nature of the reactant molecules, the presence of catalysts and the conditions of temperature, pressure, and reactant concentration. These reactions often lead to undesirable consequences in processing and handling operations. For instance, the formation of gums in liquid fuels; the production of corrosive acids by lubricant oxidation; the breakdown of long chain polymers; and the deterioration of foodstuffs and flavouring materials. The action of anti-oxidants and their application to the food, oil and rubber industries were described in papers presented by Professor C. E. H. Bawn and others before the Chemical Section of the British Association.

Recent research has shown that such oxidation proceeds by free radical mechanism—a single reaction chain may cause subsequent oxidation of tens of thousands of reactant molecules. It has also been found that autoxidation proceeds in two well defined stages; first, addition of oxygen so that the O-O bond is maintained intact with the formation of a hydroperoxide, and second, decomposition and reaction of this substance, forming diverse reaction products such as aldehydes, alcohols, acids and other chemicals. In the oxidation of a hydrocarbon it is supposed that the first stage is the production of a free radical; this then combines with a molecule of oxygen, and a subsequent reaction with another hydrocarbon molecule produces the hydroperoxide and a further free radical. Thus a chain reaction is initiated which can only be terminated by removal of the free radical from the reaction. Anti-oxidants are introduced in order to reduce or eliminate undesirable reactions, either by interrupting the oxidation chain or by influencing the peroxide decomposition so that it will not produce chain initiators. The most commonly used are those which react with the transient free radicals.

In the rubber industry the manufacture of synthetic rubbers depends largely on the polymerisation of simple intermediates but the polymers obtained are perishable materials and suffer during their service life from various effects including oxidation. The introduction of anti-oxidants may therefore retard to some extent this degradation. In the food industry, defects such as unpleasant odours and flavours or discolouration, arising from the action of atmospheric oxygen, may be inhibited by the use of anti-oxidants, but at present their use is not permitted in this country.

Anti-oxidants are of considerable importance in the oil industry, since both petroleum fuels and lubricants must have adequate oxidation stability in the circumstances in which they are used, and about 50,000 tons of anti-oxidants are used every year. Over 90 per cent. of this figure is employed in lubricants. In the future, the jet engine will impose new demands on the oxidation stability of both lubricants and fuels. It is expected, for example, that in supersonic aircraft capable of 1,500 to 2,000 m.p.h., the fuel may have to be used to provide not only the power, but also the cooling necessary to overcome the "thermal barrier." Stability will then be of prime importance.

* * *

Ladder to Success

The young would-be engineer about to start on his training might do well to ponder some figures published in a paper presented by Miss R. Stewart to the Psychology Section of the British Association. It is based on two years' research by the Acton Society Trust. Familiar questions of the day are: What opportunity is there for managers to rise from the bottom? What is the proportion of men promoted from within a firm? How does educational background affect promotion to management? How many managers are professionally qualified? What is the age of distribution of managers? Is it easier to enter middle than top management?

The educational background of managers is given in the paper as follows: 20 per cent. of all managers went to elementary school only, 33 per cent. to ordinary secondary school, 28 per cent. to grammar schools, 15 per cent. to lesser public schools and 4 per cent. to major public schools. A study of the educational background of top managers, however, reveals a very different picture. Of top managers, 8 per cent. went to elementary schools only, 26 per cent. to ordinary secondary, 34 per cent. to grammar, 22 per cent. to lesser public schools and 10 per cent. to major public schools.

From these figures it may be gathered that it is very much harder for those with no special educational or social advantages to reach top management than to enter junior or middle management. In top management there are more striking differences in educational background than in middle and junior management. Moreover it has been shown that it seems to be of greater advantage to have an arts degree than a science degree and very advantageous to have been to a major public school. However, it is also an advantage to have been to a lesser public school or grammar school. The evidence also suggested that a non-technical education would yield more benefit than a technical training and confirmed the belief that accountants have had better promotion opportunities than engineers. It was a disadvantage to have started work as a clerk, manual worker, salesman or laboratory assistant, and it appears to have been disadvantageous to have been a foreman.

The number of managers technically well qualified is quite small; only 14 per cent. of those in the sample taken had degrees in pure or applied science. If arts degrees are included, 19 per cent. of all managers had a degree. For top managers, however, the proportion rose to 33 per cent. In general, the research revealed that half the managers in the sample came up the hard way, but a separate analysis of top managers showed that those coming up the hard way could normally only reach junior or middle management. Educational advantages seemed to have been the most fundamental ones. Nevertheless, when young managers alone were considered there was some indication, as might be expected, that the successors to present managers would be better educated and more qualified. Moreover there would be fewer rising from the bottom than hitherto.

AT THIS SOAP AND "TIDE" FACTORY

where although the total employed is only 550, there are 60 of managerial status plus 60 technical and clerical staff, and where half the lower supervisory positions in the plant engineering department are held by graduates

ENGINEERS TRAIN FOR MANAGEMENT

The formal training of graduate engineers is generally considered finished by the time they have completed a two years' graduate apprenticeship. This normally consists of a period spent in each shop department and some of the offices, but rarely conforms to any specially devised training procedure. It is becoming increasingly recognised that this graduate apprenticeship is inadequate for the engineer who is destined for managerial responsibility and may even be a wasteful method of giving practical experience to the future designer or researcher.

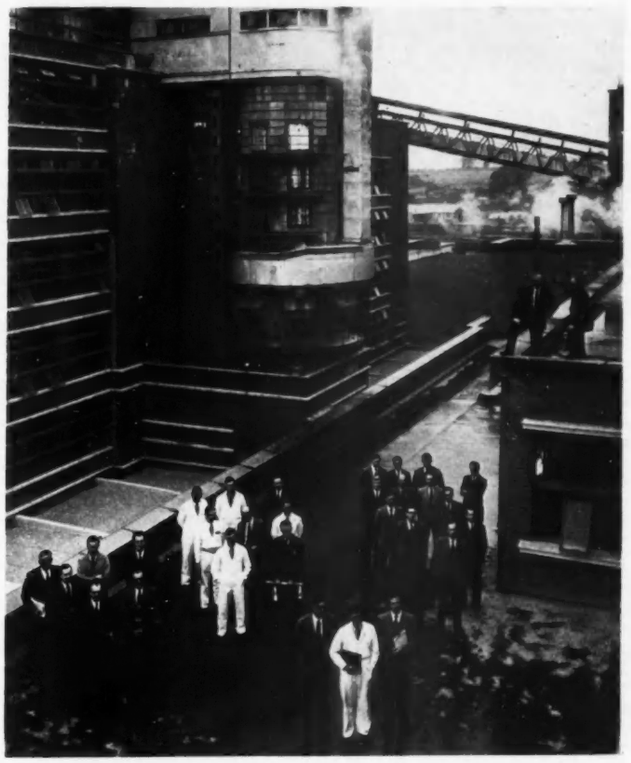
The engineering industry might sometimes take a lesson from other industries, especially from industries which, by their very nature, must employ a large number of engineers in their plant development and maintenance. The chemical and ancillary industries are of this type. One of the most elaborate and carefully thought out schemes of graduate recruitment and training is to be found in the firm of Thomas Hedley and Company, which has soap, detergent and edible product factories in Newcastle, Manchester and Thurrock (Essex). Owing to the nature of their processes the proportion of managerial, technical and clerical workers is high: at Thurrock, for instance, where the total employed is 550, there are 60 of managerial status and 60 technical and clerical. All graduates are employed in managerial grades, although all supervisors are not graduates.

The company is organised on a traditional line and staff basis, the engineering departments consisting of plant engineers, technical engineers and industrial engineers. At each factory production is broken down into product groups and process sections, and the line manager or supervisor is assisted by group and section plant engineers. The technical engineering department provides such specialised services as electrical equipment and instrumentation, while the industrial engineering department, mainly staffed by non-engineering graduates, provides guidance on method study, administers the wages department and time bonus scheme, interprets costs for line management, and works out performance factors for departments and the whole works which are used as the basis of a bonus incentive scheme for managerial staff.

MANAGEMENT SUCCESSION

The training scheme for graduate engineers, which was developed by the parent company, Procter and Gamble in the United States, but has been modified by the central training department at Newcastle, is based on a long-term plan of management succession and on the policy of all positions in a world-wide organisation being filled by promotion from within the various associated companies. Throughout the company the responsibility for training is that of the head of each department, line or staff, with guidance from the central training department at head office.

Preliminary selection of graduate recruits is carried out centrally, but each manager makes the final choice of those who are to work for him. Graduates are recruited at ages between 24 and 30 and are normally expected to have received a regular graduate apprenticeship with an engineering firm; but where this has not been done arrangements are sometimes made with a suitable firm for such an apprenticeship to be served. Whatever the newcomer's experience, he is then given a period of training lasting between four and five months which is intended to fit him for managerial posts. This training emphasises the management of people and concentrates on developing in the trainee an understanding of the extent and limits of his responsibilities and the power to distinguish degrees of importance in the job he has to carry out.



Engineering and production men at Hedley's West Thurrock factory are here seen grouped against the background of the spray drying tower. From left to right: technical engineers, maintenance engineers, trainees, production managers. The factory manager and the plant engineer survey them from a vantage point right.

WRITTEN ASSIGNMENTS

Before formal training commences, the trainee is given background instruction on the organisation, products and processes of the company and of his particular factory, after which training proceeds in two stages. The first is in basic engineering procedures covering the services, the equipment and the trades employed in the works including, if necessary, a period of basic workshop training. It is in the actual training methods employed that the most interesting innovations are to be found. All work is done to written assignments, the first of which is the study of a lengthy and detailed description of the duties of each job. Only 20 per cent. of the time is spent on practical work, most assignments consisting of a mixture of practical work, the study of literature and the writing of reports. For instance, the trainee may be instructed to study the types of pumps used in the works, to strip some of them down and measure the wear of the parts, to write a report on this, to study the literature on pumps and on the water supply and to examine the stocks of spares held in relation to the maintenance requirements. During this period he will attend special two-day courses on such subjects as instrumentation and lectures on some particular subjects such as boiler-house operation. Much of the information he requires will be given him in the form of written notes in order to save time.

This part of the training takes nine weeks and is followed by from five to nine weeks, according to the needs of the trainee, on assignments connected with the actual duties he will first be called upon to perform. During this period his assignments are designed to give him knowledge of the particular product being made and the processes involved; the special equipment in use on the plant; the maintenance rules and procedures laid down and the stocks of spares carried; and he is expected to study and become fully acquainted with the people of whom he will be in charge when his training finishes. Many of these assignments will involve discussion with the line managers and supervisors concerned.

During his training the trainee works at his own pace and plans his own work from week to week. He is not required to submit the reports which he writes on his assignments to anybody, but once a week he attends a "qualification" interview, when he sits down with the person responsible for his training at the works and with the head of the group in which he will be working and discusses the training he has been receiving. This discussion is not intended to provide an assessement of the trainee's personal progress, but to enable adjustments in the training course to be made, if necessary, to suit the individual's needs. At the end of his course the trainee has a final "qualification" session with the works manager in which the latter satisfies himself that the trainee has satisfactorily completed his training and is fully conversant with the content of his future job and how he is expected to carry it out.

SUPERVISORY POSITIONS

Perhaps even more significant than the formal scheme of training received by graduate engineers is the fact that the first jobs they receive after completing their training are in supervisory positions, in charge of half a dozen or so craftsment with a call on the services of specialists and machine shops. As a result, half the lower supervisory positions in the plant and technical engineering departments are held by graduates, even the boiler-house at one factory being in charge of a Master of Science in Chemical Engineering. Obviously such a system envisages opportunities for fairly early promotion based on expanding company activities and, in practice, engineers stay at this level about three or four years during which time they will probably be moved around into different departments. Rating development records are kept of each employee and the aspects of these records which are considered within the employee's own control are regularly discussed with him by the head of

his group, the departmental head and the works manager.

At first sight this company would seem to be making an extravagant use of highly qualified young engineers, but this must be considered in the light of the rapid growth of the company's activities and consequent growing need for well trained engineering managers. From the trainee's point of view it might be thought that the training is rather narrow but, bearing in mind that most trainees will have already completed a graduate apprenticeship, the assignment method, even if applied to a limited range of processes and plant, is well calculated to develop powers of judgment and clear thinking, while the precise definition of each job and its responsibilities encourages the development of initiative and the taking of individual responsibility up to the limit. Even more important is the insistance on the human and administrative aspects of the job; the opportunity to practise these at shop-floor level, denied to so many graduates destined later on in life for management positions, must be of incalculable advantage. In addition, the company benefits from the application of fresh, well trained minds to maintenance and technical problems associated with day-to-day production.

In every industry the detailed problems of training are, no doubt, different but there would seem to be certain principles in this scheme which should be capable of universal application, above all to graduate apprenticeship training itself. They are very similar to those on which the experiment at Napier's carried out by Messrs. Marples, Radford and Reddaway was based and they are certainly worth further study by those concerned with the training of graduate engineers.

Letters to the Editor

THICK WALLED CYLINDERS UNDER INTERNAL PRESSURE

SIR, We have read the further contribution by Mr. H. G. David and Mr. S. D. Hamann in your issue of last week, page 292, to our article on ultimates pressures. As we pointed out at the time the equation for ultimate pressure (not yield) suggested by Helmut Leinss (ENGINEERING, July 29, 1955) would reduce to the mean-diameter formula

$$p_{max} = \frac{2(K-1)}{K+1}\sigma$$

if the constants in his equations were 1·00 instead of 1·02 (i.e. α_1) and 0·500 instead of 0·456 (i.e. β). We have since then estimated the ultimate pressure for several alloy steels, which we are at present testing, and we find there is remarkable agreement between the values predicted by the empirical mean-diameter formula and the technically more correct method suggested by Manning (ENGINEERING, vol. 159, pages 101 and 183, 1945). Consequently we feel that the extra constants involved in the equation proposed by Helmut Leinss are hardly justified at the present.

With regard to the yield of thick tubes, there is no justification for an empirical expression of the form suggested by Helmut Leinss, as a very simple expression can be derived on the basis of the von Mises criterion of yield, which has been experimentally fully justified by Cook (*Proc. I. Mech. E.*, vol. 126, 1934) and by Morrison (*Proc. I. Mech. E.*, vol. 159, 1951). According to the von Mises yield criterion, the yield pressure of a thick tube is given by

$$P = \frac{K^2-1}{K^2}q$$

or

$$P = \frac{K^2-1}{K^2}\frac{f}{\sqrt{3}}$$

where q is the yield in shear which is easily found from a torsion test, and f is the yield in a simple tension test.

One of the present writers has also verified this yield criterion as applied to thick tubes of an alloy steel, and found very good agreement (see Crossland and Hill, *Journal of the Mechanics and Physics of Solids*, vol. 2, page 27).

Yours faithfully,

B. CROSSLAND and
J. A. BONES.

University Engineering Laboratories,
University of Bristol.

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PHYSICAL MEANING OF SECTION MODULUS

SIR, The concept of the "section modulus" used in the theory of pure bending of prismatic bars (the "second problem of Saint Venant") possesses simple physical meanings which are, in my opinion, seldom brought out with all possible clearness in the standard texts on the subject.

For, consider the basic equation giving the extreme fibre stress σ of a prismatic bar in pure bending as a function of the bending moment M, the moment of inertia I of the section, and the distance c from the neutral axis of the bar to its extreme fibre, then

$$\sigma = \frac{Mc}{I} = \frac{M}{S} \quad . \quad . \quad (1)$$

where S is the section modulus.

Assume now that the bending moment is unity (that is to say, one unit of length × one unit of force); the corresponding extreme fibre stress σ_1 will be:

$$\sigma_1 = \frac{c}{I} = \frac{1}{S} \quad . \quad . \quad (2)$$

Consequently:

$$\sigma = \sigma_1 M \quad . \quad . \quad . \quad (3)$$

This equation shows that the actual extreme fibre stress is equal to the "unit-moment stress" σ_1 (that is to say, the maximum stress associated with a unit bending moment) multiplied by the actual bending moment M acting at the section.

The equation shows also that the section modulus is the reciprocal of the unit-moment stress.

Again, taking in equation (1), $\sigma = 1$ (that is, one unit of force per unit of area) the corresponding "unit-stress-moment" M_1 would be:

$$M_1 = \frac{I}{c} = S. \quad . \quad . \quad (4)$$

so that:

$$\sigma = \frac{M}{M_1} \quad . \quad . \quad . \quad (5)$$

This equation states that the maximum stress in a bar in pure bending is equal to the bending moment acting on this bar, divided by the "unit-stress-moment" (that is, the bending moment associated with unit maximum stress). The latter is, precisely, what is usually called the "section modulus" S.

From equations (2) and (4) it is seen also that the "unit-stress-moment" and the "unit-moment-stress" are mutually reciprocal quantities:

$$\sigma_1 M_1 = 1.$$

The physical dimensions of the "unit-stress-moment" are, of course, those of the "section modulus" (that is, length^3), for:

$$M_1 = \frac{\text{moment}}{\text{stress}} = \frac{FL}{FL^{-2}} = L^3 = S. \quad (6)$$

Very truly yours,

MICHAEL DANILOFF.

Special Systems Section,
Raytheon Manufacturing Company,
Wayland Laboratory,
Wayland,
Massachusetts, U.S.A.

August 17, 1956.

Obituary

ENGINEER VICE-ADMIRAL SIR REGINALD W. SKELTON

Former Engineer-in-Chief of the Fleet

It is with regret that we note the death of Engineer Vice-Admiral Sir Reginald W. Skelton which occurred at his home, Meadow Cottage, Aldingbourne, Chichester, on September 5.

The third son of Mr. William Skelton, of Long Sutton, Lincolnshire, Reginald William Skelton was born on June 3, 1872, and educated at Bromsgrove School, Worcestershire. His naval career began in 1887 when he entered the Royal Naval Engineering College, Keyham, as a naval engineer student. On the completion of the course he obtained a second-class certificate. In 1892 he was promoted to be assistant probationary engineer and from that year until 1900 served in various ships, including periods from 1894 to 1897 as assistant engineer in H.M.S. Centurion, the flagship of the China Station, and from 1899 to 1900 in H.M.S. Majestic, the flagship of the Channel Squadron. In 1900 Skelton was appointed to superintend the building of the vessel Discovery for the National Antarctic Expedition and he served as chief engineer in the expedition from 1901 to 1904, under the late Captain R. F. Scott. It is interesting to note that in Scott's *Voyage of Discovery*, many tributes are paid to Skelton's technical skill, resourcefulness and adaptability.

From 1906 onwards he was in the submarine service and, on the outbreak of war in 1914, was appointed to H.M.S. Agincourt. For gallant conduct during the battle of Jutland he was awarded the D.S.O., and the Russian Order of St. Stanislas. In 1918 Skelton was promoted to the rank of engineer captain and in the following year was created a C.B. and a C.B.E., for outstanding services as engineer officer on the staff of Admiral Sir J. Green, at Archangel on the White Sea. He also received the Russian Order of St. Ann.

After service as fleet engineer officer on the Mediterranean and Atlantic Stations, Captain Skelton was promoted to the rank of engineer rear-admiral in 1923. Promotion to engineer vice-admiral came in 1928 and in this same year he was made Engineer-in-Chief of the Fleet, at the Admiralty. For his services he was created a K.C.B. in 1931; he retired in 1932.

In August, 1936, Sir Reginald was elected a director of John I. Thornycroft and Company, Limited, engineers and shipbuilders, Smith-square, London, S.W.1. He was also for some years a director of Foster, Wheeler, Limited, London, but relinquished this position in April, 1942. Sir Reginald had been a member of the Institution of Mechanical Engineers for 50 years, having been elected in 1906. In January, 1930, he delivered the third Thomas Lowe Gray Lecture on "Progress in Marine

Engineering." He was then a member of Council of the Institution. Sir Reginald was made a member of the Institution of Naval Architects in 1928.

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MR. G. M. WRIGHT, C.B.E.

We regret to record the death of Mr. G. M. Wright, which occurred recently in his sixty-sixth year. He was well known for his pioneer work on radio communication during the First World War and, at a later date, for his researches into direction finding and facsimile telegraphy.

George Maurice Wright received his technological education at Sheffield University and, after obtaining a Bachelor's Degree in Engineering, joined Marconi's Wireless Telegraph Company in 1912. Initially, he worked in the Research Department as assistant to C. S. Franklin and H. J. Round. During the First World War, however, he was attached to the Admiralty for work on direction finding and was closely associated with the development of the network of stations which kept watch on the movements of the German Naval forces and the Zeppelin Fleet. He was also engaged on other special duties for which he was granted a commission in the Royal Naval Volunteer Reserve.

On the conclusion of hostilties, he rejoined the Marconi Company and was placed in charge of research and development work on direction finding. Subsequently his activities were extended and he became Chief of Research, in which position he gained an international reputation. Shortly before the outbreak of the Second World War he rejoined the Admiralty and, after being again engaged on work in connection with radio intelligence and direction finding, was appointed Assistant Director of Scientific Research. During the latter half of the war he was Chief Scientist of the Admiralty Signal Establishment and was responsible for the technical side of both signals and radar.

He rejoined the Marconi Company for the second time as engineer-in-chief in 1946 and served in this position until his retirement in 1954.

In 1950, Mr. Wright was made a Commander of the Order of the British Empire for his services. He joined the Institution of Electrical Engineers as a member in 1946. He was the first member of the radio manufacturing industry to be appointed to the Radio Research Board, on which he served for two periods.

* * *

WORK BY DESIGNERS

A sense of growing awareness in industry of the place of the industrial designer is demonstrated at an exhibition entitled "Designers at Work," now being held at the Design Centre, 28, Haymarket, London, S.W.1. This special display has been organised to illustrate the work of the Council of Industrial Design's Record of Designers. The purpose of the Record, which has over 2,000 designers on its books, is to provide the manufacturer who has a design problem with a short list of possible consultant or staff designers with special qualifications for the particular job. The service is entirely free of charge.

At a Press conference on the opening of the exhibition, Sir Norman Kipping, Director General of the Federation of British Industries, expressed the hope that manufacturers would rid themselves of the belief that to employ the services of a consultant was a reflection on the company staff. "Good design," he pointed out, "seldom results in higher price," and it was to be wished that "more firms will raise the consideration of design to the boardroom level."

The object of the exhibition is to show what has already been achieved by co-operation between the Council of Industrial Design and industry, and the exhibits include details of three typical products in case history form, from the manufacturer's initial approach, through the designer's sketches to the final article. Sections are included on display and interior design, packaging, furnishings and engineering design.

Weekly Survey

Cover Picture. *Gears may be cut and finished by many different methods—hobbing, grinding, lapping and shaving are a few. The picture this week shows a double helical gear being cut on a gear-shaping machine. The gear, which has* 150 *double helical teeth and is made of cast iron, has a diametral pitch of* 2½ *and a face width of* 7¼ *in.*

* * *

A Stake in Automation

Through their purchase of Sentinel (Shrewsbury) Limited, Rolls-Royce have several new vistas, not least of which is the production of machine tools for automation. They are the second large company to have entered this field recently, the first being E.M.I. Limited, and they are unlikely to be the last. There is a trend, now gathering momentum, towards the design of special machines as opposed to the adaptation of existing types of machine tools. The resources required to undertake the necessary development work are beyond the means of most companies, even large ones, since the returns of the investment are unlikely to be substantial for several years. This was the reason given by Metal Industries Limited for the sale of Sentinel. In the words of their chairman, Sir Charles Westlake, "the simple fact is that we cannot afford to finance it further. We lost over £500,000 before taxation last year."

The entry of companies such as Rolls-Royce and E.M.I. into the machine tool industry is likely to have a major impact on its development. It is a challenge to existing manufacturers and is likely to provide a powerful stimulus to rapid changes in their range of products. It is also a striking recognition of the potential of automatic methods of production. As Mr. J. F. Coates, of the Engineering Laboratory, Cambridge University, pointed out in his paper to the British Association, the main advantage of automation should be a large increase in the productivity of certain industries, partly by making possible a full 24 hour working of the plant. The cost advantage of automatic production methods is likely to be too great for anyone not using them to continue in competition. This is already happening in the United States and must considerably increase the rate at which the transition will take place.

Sentinel's other main products—steam and Diesel locomotives—will bring Rolls-Royce into a field which they have begun to enter with their C-range of Diesel engines as power units for railcars. They intend to continue to make these products, and to use any surplus capacity to meet the demands of their own expanding business. It is hardly surprising that Sentinel's 1,700 workers greeted the announcement of the deal with loud applause.

* * *

Impact of Technological Change

It is gradually being born in on the British public and, in particular, those who work in industry, that their future livelihood depends on their willingness to accept substantial changes in the goods they make and in the materials from which and the methods by which they make them.

In an interesting article in *Occupational Psychology*, Professor Roger W. Russell examines the human problems of such change and the extent to which modern research in the social sciences can contribute to their understanding and their solution. He recognises four main effects: on individual workpeople, on the organisation of the work groups, on the organisation (including the management methods) of the firm and on relationships and prestige in the social structure of the community in which workpeople live.

While recognising that there is no simple formula to account for all the many conditions which affect human behaviour during technological changes, he defends those who, from industrial experience and systematic research, are endeavouring to provide knowledge on which better decisions can be made when changes are being considered and reliable information which will assist in reducing the human stresses of such periods. As evidence he quotes a number of published studies and statements. Perhaps one of the most important factors in worker acceptance of change is full employment and this, as he pointed out, is based on reliable information on markets. He also stresses the great value of participation by all concerned in the planning of changes and the need for checking afterwards on all human factors affected in order to ensure that the plan is functioning properly.

* * *

Wind Driven Generator for Algiers

During the past few years considerable attention has been directed to the possibility of utilising the wind as a supplement to the more normal methods of generating electricity. In particular the British Electrical and Allied Industries Research Association have been conducting surveys on the availability of this form of power at certain sites in the Orkney, Hebridean and Channel Islands, as well as in the North and North West Ireland and in the western coastal districts of Great Britain. Similar surveys have also been conducted in other countries.

Both the Central Electricity Authority and the North of Scotland Hydro-Electric Board have encouraged this work by purchasing experimental wind-driven plants: one 100 kW unit for which Enfield Cables Limited were the principal contractors and others of a different type but of the same output, for which John Brown and Company (Clydebank), Limited, were responsible.

The former unit, which has already been described in detail in ENGINEERING, (vol. 179, page 371, 1955), consists of a wind generator which works on the "depression" principle devised by the late M. J. Andreau. The propeller blades of this machine are hollow; and as the force of the wind causes them to rotate, so air is discharged through the blade tip outlets owing to centrifugal force. As a result, air is drawn through a turbine near the base of a 100 ft. tower, up through the tower structure, then through the propeller hub to the blade tips. The turbine is coupled through a free-wheel mechanism to a 100 kW synchronous induction alternator of English Electric manufacture.

This plant was initially installed on a site at Prae Wood, near St. Albans, where experience was gained in its erection and where a certain amount of experimental work was carried out to determine its performance. It was intended to re-erect it on a site in Wales where the wind conditions would have been more favourable and where further practical results would have been obtainable. As, for various reasons, this was not found to be possible, the unit has now been dismantled and has recently been shipped to Algiers where Electricité et Gaz d'Algerie propose to erect it on a site where the wind conditions are such that it is hoped some useful data will be obtained. The information would be helpful to the Central Electricity Authority aud the British Electrical Research Association in this country. It will also form a useful addition to that which has already been collected, provided that the test conditions are correlated with those in this country.

The ship on which the wind plant was transported to Algiers is the "Marie Louise Le Borgne" of the Compagnie Charles le Borgne. She has only just been completed at Nantes, whence she sailed to Southampton on her maiden voyage to take on the wind power plant.

* * *

Young Managers In Residence

The fourth annual Oxford University Business Summer School is now in full session at Merton College. Organised by a committee composed of members representing industry and the University, under the general control of the

University Appointments Committee, the school has established itself as one of the most successful attempts in this country at executive development.

This year 89 applications were received for places, of whom 44 were selected, mainly as a result of interviews, and their standard is considered the highest of any school so far held. Students are of ages which range from 26 to 34 and come from a variety of occupations in private and nationalised industry and the Civil Service, including engineers, accountants, bank managers, sales managers and advertising executives.

The scheme of studies, which is intended both to draw attention to management techniques and to enable students to understand the British economy as a whole, covers three main topics: (1) the efficiency of the firm; (2) the working and present condition of the economy; (3) the requirements of economic progress. The work of the school follows the now normal course of group discussions as well as class instruction, the tutors being supplied by the University and the Director from industry.

In addition, there is a large number of lectures covering subjects as wide as: growth of the firm, employment and prices, balance of payments, trade unions, taxation and industry, research and development, and a Labour view of industry. Many of these are given by specialist visitors from outside and some are intentionally designed to provoke controversial discussion among the students.

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Direct Current for the Cross-Channel Connection

The joint committee which was set up in 1951 by the Central Electricity Authority and Electricité de France, to consider the possibility of a cross-channel connection between the two countries, has recommended that it should be effected by means of a single direct-current cable capable of transmitting between 120 and 150 MW at 200 kV. This recommendation, it is officially stated, has been based on the success of the 100 kV interconnection between the mainland of Sweden and the island of Gotland, and on the progress that has been achieved in the development of high-power mercury vapour mutators which has rendered it possible that the voltage and power loads suitable for the cross-Channel connection will be obtainable at an early date. This recommendation therefore represents a reversal of previous policy as interesting and as important as that of the British Transport Commission in adopting high-tension single-phase alternating current at an industrial frequency for traction purposes in place of the previously favoured moderate voltage direct current. The reasons are not dissimilar and are largely, if not wholly, economic, for the project of transmitting 150 MW at 132 kV on the three-phase alternating-current system previously envisaged would have involved the laying of four single-core cables, of which one would have been in reserve. On the other hand, the direct-current system will require only one cable and will thus be cheaper, besides exposing the continuity of the supply to lower risks from navigational and fishing causes.

From the engineering point of view, direct current will have the important advantage, it is considered, of allowing the British and French systems to control their frequencies independently and to regulate the agreed interchange of load with greater precision than would be possible with an alternating-current connection. Moreover, to forestall criticism by those who may object to the change, it may be pointed out that the investigations that have already been made into this project will not be wasted. The results of the systematic study of the forecast of electricity load trends in the two combines, which theoretically justified the interconnection, will will still be applicable, as will the experience that has been gained under practical conditions into the manufacture and laying of the high-voltage cables necessary for this purpose. It is hoped that work on the revised project will begin early next year and that the installation will be ready for operation in 1960. It will no doubt, as do all engineering projects, give rise to day-to-day problems which will require skilled investigation, but apart from its technical and political importance, both of which are great, its outstanding feature is the enterprise which it shows in taking the risk of adopting something new.

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Motorcycles—Heavy or Light?

The last few years have seen a phenomenal increase in the popularity of the small motor-cycle —particularly the low-powered auto-cycle and motor scooter. Hitherto British manufacturers have been notably slow to take up production of these designs, but there have been signs recently of some rethinking on the part of the British motor-cycle industry. B.S.A. Ltd., for example, have announced plans for the production of a motor scooter which they hope will be an answer from this country to the challenge of the ubiquitous Italian Vespa and Lambretta. Other major manufacturers have also been reported to be developing their own designs. It is probable that potential buyers may have a chance to compare the first fully British designs with the continental models at the Cycle and Motor Cycle Exhibition in November.

There is, however, some doubt as to whether the British developments have not come too late to be an effective answer to continental competition. German exports of light motor-cycles in the first five months of 1956, at £4·3 million, were 49 per cent. up on the comparable period of 1955, and accounted for 63 per cent. of total motor-cycle exports as against 52 per cent. in January to May, 1955. Italian exports of motor-cycles, of which a high proportion must be in the light low-powered class, rose by 32 per cent. in the first five months of this year compared with the same period in 1955. Italian exports to their profitable United Kingdom market, while being relatively small in global amount, accounted for over 20 per cent. of that country's total exports, and showed virtually a three-fold increase over the period January to May, 1955.

When comparing total exports of all types of machines, however, British manufacturers have not fared as badly as suggested in some quarters. Between January and May, 1956, Italian exports rose by 32 per cent., German by 20 per cent., and United Kingdom exports—still the largest in total values—by 15 per cent. Where the figures are disturbing, however, is in trade with Europe, which is fast becoming a German monopoly. British exports of motor-cycles to Sweden, for example, fell from £598,000 in the first five months of 1954 to £83,000 in the comparable period of 1956, while exports to Denmark declined from £318,000 to £77,000 in the same period. Yet Britain is still predominant in exports of heavier models from 250 c.c. upwards. In particular, U.K. exports to the United States, where the call is for power rather than lightness, have risen by over 100 per cent. since 1954 to a total of £1·4 million in the first seven months of 1956. German exports of comparable machines have meanwhile fallen, and the recent announcement by three German manufacturers of their intention to pool their sales and production programmes is further evidence of this trend.

The implication is that British manufacturers should concentrate on improving technical designs of their most popular selling lines in motor-cycles, particularly now that high-octane petrol, giving even more power from a given capacity, is becoming widely available. This may be a more profitable development for the future than trying to compete with the now firmly entrenched continental lightweights.

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Hydraulic Transmissions

The rapid growth since the war in the use of fluid couplings for the transmission of power between the prime mover and the driven machinery was underlined by the public issue of shares made last week by Fluidrive Engineering Company, Limited. Fluidrive were formed in 1930 as a private company to acquire from Hydraulic Couplings Patents, Limited, the right to manufacture and sell the Vulcan-Sinclair fluid couplings. From its inception, the company's business has been managed by Mr. Harold Sinclair, now chairman and managing director, who has made an important contribution to the development of the fluid coupling based upon the invention of the hydro-kinetic principle of transmitting power made by Dr. Föttinger of the Vulcan Company, Stettin, in 1905. In addition, the company hold a non-exclusive licence from S.S.S. Gears, Limited, to manufacture synchronous self-shifting gears. The rapid expansion of the fluid coupling business has tended to delay progress on the S.S.S. range of clutches and gears although it is now expected to be at a faster rate. Fluidrive employ 600 people in two factories, at Isleworth and Bracknell.

The use of fluid couplings, which began in this country for the speed control of induced and forced draught fans in power stations, has spread to a wide range of industries for the smooth transmission of power to conveying and haulage equipment, to oil drilling and slush pumps, to cranes, excavators, locomotives and rail-cars, buses, lorries and cars, Fluidrive do not mass-produce their couplings for automotive applications but they have made considerable headway in the locomotive and rail-car fields where the combination of the Fluidrive-S.S.S. gear has overcome two of the major technical problems associated with the use of Diesel-mechanical power units up to about 550 b.h.p. The break in tractive effort and ensuing peak efforts at gear changes have been eliminated, and the system makes possible the utilisation of greater horse-power, and so greater torque, at low engine revolutions. Easy, smooth gear changing which lightens the task of the driver or operator is likely to become even more widely adopted. The loss of power due to the use of fluid flywheel transmissions is unlikely to alter the trend towards semi-automatic and automatic gear change, particularly where there are special problems of frequent speed changes, stopping and starting. The progress of Fluidrive is evidence of this trend.

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Cause of Road Accidents

The Pedestrian Association have requested the Ministry of Transport to produce a more searching analysis of the causes of road accidents. Government spokesmen have admitted that the present methods of analysis might not reflect the number of accidents due to vehicle defects, and the value of the statistics concerning drink and road defects has been questioned. As a result, the road accident statistics will be once again subjected to expert review and some changes may be made.

The frightful toll of the roads goes on unabated, although the June and July figures were slightly lower than a year ago, possibly because the bad weather kept some cars off the road. The Ministry's analysis of 100,000 accidents shows that 4·6 per cent. were due to drivers turning right carelessly, 2·3 per cent. due to cyclists doing the same and 1·4 per cent. due to motor cyclists going too fast. Thus over 8 per cent. of accidents were due to clearly demonstrated negligence, and a great many more to inconsiderate behaviour on the road, misjudgment and to ignorance of the Highway Code. Mechanical faults in vehicles, such as defective brakes, tyres, or steering, doubtless lead to accidents but the proportion of such causes is likely to be negligible. Lack of elementary prudence, drink and excessive speed are, on the other hand, very heavy contributors. It is against this that the road safety campaigns are directed.

The number of road casualties last year rose faster than the volume of motor traffic. This, surely, is the most disturbing of trends: motor cyclists, pedal cyclists and motor-car drivers and occupants provided casualty rates which were

higher than the previous year's by 22 per cent., 17½ per cent. and 17½ per cent., respectively. These increases were all far above the overall average increase. The ill-considered daring of the young is doubtless a major contributing factor, as is the habit of "one for the road," but ignorance and lack of skill remains a heavy contributor. Television and school lectures could probably reach a very wide public. In 1955 one in every 200 of the population was either killed or seriously injured on the road.

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Petrol Injection and Automatic Oil Burners

Two competing companies—Joseph Lucas (Industries), Limited, and Simms Motor Units, Limited—have announced interesting developments likely to lead to an extension in their range of products. Joseph Lucas, like Simms, have been engaged in the large-scale manufacture of Diesel fuel injection equipment for many years. They have now concluded an agreement to exchange all patents and technical information relating to petrol injection systems with the Holley Carburettor Company of Detroit. That company have, from the earliest days, been the leading suppliers of carburettor and ignition equipment to the Ford Motor Company. In more recent years they have become established as suppliers of fuel-control systems to the United States aircraft industry. Joseph Lucas have been engaged on the development of a petrol injection system over the past 10 years, and the new agreement may well lead to the eventual eclipse of the carburettor. So far as is known only Mercedes use petrol injection, on their faster cars.

Simms Motor Units have entered the automatic oil-burner field by acquiring the business of R. F. Landon and Partners, who have developed since 1947 a range of small automatic oil burners and are one of the leading producers of oil-firing equipment in the country. The lack of an efficient low-priced automatic oil burner has considerably retarded the public acceptance of oil-fired central heating and hot-water domestic boilers. Although central heating is unlikely, in this country, to make the spectacular progress it has made in the United States and the Continent, the high and rising price of solid fuels and the desire to have automatically-controlled systems are likely to create a good demand for oil-fired boilers. As Simms point out, the demand "is accelerating in parallel with the rising cost of solid fuels, both in industry and the home." R. F. Landon oil-burner units will be manufactured at a new factory at Colnbrook, Buckinghamshire, where they will also make various oil-firing accessories.

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Stronger Polyvinyl Chloride Sheeting

The quality of the polyvinyl chloride (P.V.C.) sheeting made immediately after the last war left much to be desired, but by its novelty and availability in the form of ultra-lightweight raincoats, curtains and tablecloths at a time when most materials were in short supply, it created a great deal of interest. As better raw materials and manufacturing plant became available, great improvements were made in the quality and finish of the sheeting and a first British Standard Specification, B.S. 1763, issued in 1951, contained clauses governing the manufacture and testing of sheeting of nominal thickness in the range 0·004 to 0·015 in., for producing clothing, curtains and for similar purposes. This has now been revised, broadened and brought up to date and, in addition, a new standard B.S. 2739, has been issued. The latter deals with the manufacture, testing and marking of thick P.V.C. sheeting, ranging from 0·010 in. to 0·035 in. in thickness and used for such applications as the rear windows of motor cars, wallets for tools, brief cases, canoes and ducting for mine ventilation.

Speaking at a Press meeting held in London to announce the publication of the two new standards, on September 5, Mr. C. C. Last, chairman of the British Plastics Federation, stated that the two specifications now virtually covered all P.V.C. sheeting. He also emphasised that the level set by these standards was higher than that required by any other plastics standard in the world.

Both publications include stringent control tests for thickness, tensile strength, dimensional stability, tear strength, adhesion of print, ply adhesion of laminated sheeting and the retention of embossed surfaces. Type tests are also included for low-temperature extensibility, extensibility after heat ageing, and colour fastness.

Moreover, for the first time, B.S. 1763 contains a section on what is termed "Recommended Procedure for Informative Labelling." In this section, manufacturers are advised to provide detailed advice to fabricators and retailers of thin P.V.C. sheeting, and to users of articles made from it. This, as pointed out by Mr. Last, would enable the fabricators and retailers of the sheeting to pass on to the consumers information which enabled them to reach the same standard in the use of an article as the manufacturer had achieved in its production.

The two specifications are obtainable from the British Standards Institution, 2 Park-street, London, W.1. The post-free price of B.S. 1763 is 10*s*. and of B.S. 2739, 6*s*.

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Australian Prospects

There are powerful cross-currents at work in the Australian economy, and the outcome of the present disturbance is of the greatest importance to British engineering. There is a distressing state of inflation, coupled with a deficit on external trade. There is a record wool crop and first rate prospects of an excellent selling season, leading to a fat wool cheque. There is growing dissatisfaction with the limiting effect of Imperial preferences on Australia's trade with foreign countries.

The Australian Government's imposition of severe restrictions on imports has eased the balance of payments position. It has also tended to push up prices, since it promotes a shortage of goods whilst demand has not been sufficiently reduced by credit restrictions, higher taxes and other anti-inflationary measures. Yet in his Budget speech, Sir Arthur Fadden, the acting Prime Minister, could give no hope of any early relaxation of import controls. Severe restrictions are to stay: "unless there is a major improvement in our export earnings, or unless capital inflow is much larger than in recent times, it is difficult to see the position being much alleviated in the immediate future." Yet the Minister for Trade, Mr. J. McEwen, announced that the Commonwealth Government had submitted proposals to the British Government for a revision of the Ottawa agreement to reduce tariff preferences which impose "an excessive cost burden" on Australian industries using imported raw materials, capital goods and other aids to production.

The long and short of it is that Australia is bent on rapid expansion of her own industry. The rate at which industry is growing is faster than in any country in the western hemisphere, and the task of keeping so rapidly moving an economy in balance is a tremendous one. The immigration rate is cited as a major cause for inflation; it is also a vital means of expansion. Import controls are said to be essential to the country's solvency, yet cheap and plentiful import of raw materials and capital goods are equally essential to the growth of industry. Tariffs contribute to high costs but the general lowering of tariffs must threaten the young industries on which growth depends. The way out of these difficulties must be found in abundance—of workers for secondary industry, of capital for new schemes, for expansion of agricultural and industrial production and for the exploitation of the country's natural resources.

Australia, like any rapidly growing concern, is finding that its greatest difficulty is to keep solvent. Its people must learn to save and to invest their savings. This country, if it is to retain this most valuable market, must increase its investments. Gross capital formation, at between 25 and 30 per cent. of the gross national product, is higher than in this country, the United States or Western Germany. The prospects for British goods and services are vast, provided Britain plays her part in assisting rather than arresting growth. Australia's desire to have freer access to world supplies of the goods she needs is legitimate enough. More wool, and the prospects of a better price for this year's crop, will help relieve the present situation.

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British Locomotive Builders

The recent decision of the North British Locomotive Company, Limited, to defer consideration of the dividend on the 5 per cent. preference shares until the 1956 results are available draws attention to declining profit margins and intensified competition in the locomotive building industry. Speaking at the annual general meeting of the company in May last, the chairman said there was a reasonably well filled order book but most of the orders had been secured in the face of very keen competition. He gave details of tenders submitted to the Indian Government for a particular type of locomotive for which the British price, which contained virtually no profit, was £38,870 compared with tenders ranging from £30,500 to £31,862 from Japan, Poland, Hungary and Czechoslovakia. The German tenders were slightly higher than the British.

For the first six months of 1956, total U.K. exports of locomotives amounted to 456, valued at £9·6 million, compared with 437 valued at £7·9 million for the corresponding period of 1955 and 540 valued at £9·8 million in the first six months of 1954. Over this period exports rose substantially to Rhodesia, Kenya, India and "other Commonwealth countries including the Irish Republic," but fell to the Union of South Africa, Spain, Iran and Brazil. While exports of steam locomotives fell from £6·1 million in the first six months of 1954 to £2·5 million, those of Diesel locomotives rose from £2·4 million to £6·1 million.

The independent locomotive builders also have on hand important orders from the British Transport Commission for Diesel and Diesel-electric locomotives under the modernisation plan for British Railways. These orders were particularly welcome since British locomotive builders have in the past been severely handicapped by the lack of a home market due to concentration of work at the railway workshops. The statement of policy issued by the British Transport Commission on the placing of these orders was not, however, very specific with regard to the future. There is therefore some anxiety among the private locomotive builders as to how far, when present orders are completed, the Commission will undertake new building in their workshops. While it would obviously be uneconomic to ignore the capacity represented by these workshops, it is to be hoped that the scale of ordering in future will be sufficient to permit the placing of sufficient orders with the private builders to enable them to compete successfully in export markets.

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Vulcan Foundry

For the first time since its foundation in 1830 (apart from the war years) there are no steam locomotives being built by the Vulcan Foundry, Limited, at Newton-le-Willows, Lancashire—a commentary on a contracting market. Such a possibility had been foreseen, and since the company joined the English Electric group about 18 months ago, a considerable amount of re-organisation has taken place to increase the capacity for building Diesel, Diesel-electric and electric locomotives. The change does not

exclude steam, and the company will continue to tender for contracts, but merely makes the adjustments necessary for a changing market.

At the moment, orders in the shops at Newton-le-Willows include main line Diesel-electrics for New Zealand and for Buenos Aires, Diesel-electric shunters for the Netherlands and main-line electrics for South Africa. In addition, equipment is being produced for British Railways. Diesel engines are also to be made there.

The addition of the Newton-le-Willows plant to the Dick Kerr factory at Preston represents a great increase in locomotive capacity for the English Electric group with consequent reduction in delivery dates. At Preston, Diesel-electric locomotives for Malaya and Jamaica are in the shops, as well as electric locomotives for South Africa. Here again, a considerable amount of equipment (including engines) is being made for British Railways. Preston is also the home of the Deltic locomotive, which has been in revenue-earning service with British Railways and is now undergoing dynamometer trials between Carlisle and Skipton to assess the results of some modifications.

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Electric Locomotives Modified

The basic designs for the electric locomotives now in use on the Manchester-Sheffield-Wath sections in the Eastern Region of British Railways were prepared before the war. Since then, considerable theoretical experience has been gained with this class of equipment and these particular locomotives have been subjected to the full stresses of daily operation under arduous conditions since 1954. It is therefore not surprising to learn that, although the equipment in the main has proved satisfactory, certain modifications have become desirable.

The most important is the addition of rheostatic braking to 58 Bo + Bo locomotives. At the present time all the electric locomotives on the Manchester-Sheffield-Wath line are equipped with regenerative braking. This has, of course, the economic advantages that when it is in use power is returned to the overhead contact wire and at the same time wear on the brake blocks and wheel tyres is reduced. On the other hand, it cannot be used to reduce the speed below about 16 m.p.h. and this has led to difficulties in matching the uphill and downhill speeds on the long heavy gradients, which experience has shown to be necessary. These gradients are a feature of the line, a point which is of importance in maintaining the control of heavy trains of loose coupled unbraked freight wagons on the long falling inclines. To overcome this difficulty the Bo + Bo locomotives are to be fitted with rheostatic braking, which will come into action when it is necessary to stop the train or to reduce its speed below about 16 m.p.h. It will thus be possible to reduce the speed to about 3 m.p.h., keeping the brake blocks and tyres cool for the final stop from a much lower speed.

Two minor modifications have been necessitated by the climatic conditions and by the fact that the line crosses the Pennines and rises to a height of nearly 1,000 ft. above sea level. The first of these is the provision of improved cab heating. The present low-tension equipment has proved insufficient, particularly on the exposed sections of the line, since the current available for heating has been limited by the capacity of the 5 kW motor-generators which also have to provide power for lighting and for the control systems. To reduce the load on the motor generators and to improve the heating, the low-tension heaters are being removed and high-tension heaters of greater capacity are being fitted both to the Bo + Bo and seven Co + Co locomotives. At the same time, as the result of experiments, 64 of the locomotives are to be fitted with air-operated wind-screen wipers in place of the hand-operated wipers now in use so as to improve the visibility during the periods of inclement weather which are frequently encountered. This work of conversion is being carried out by Metropolitan-Vickers Electrical Company, Limited, who were the main contractors for the electrical equipment when the locomotives were built.

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Data Processing and Transmission

A new Anglo-American company has been formed for the production of "precision synchros, servo motors, resolvers and tachometer generators, radar sweep circuits, phase shifters and accurate data transmission systems." The company, Ketay Limited, is a joint venture by the Plessey Company, Limited, and the Norden-Ketay Corporation of New York, and is yet further evidence of the rapid growth of the data processing industry. The establishment in this country of a British subsidiary of the Benson-Lehner Corporation was discussed in a Weekly Survey note in the issue of June 22. Another development announced last week was the establishment by Rapid Magnetic Machines Limited, of Birmingham, of a department specialising in the development of automatic feeding and handling devices.

All Ketay's products will be made to Plessey's specifications. They will be produced in a very wide range of sizes and outputs so that they can be used in varied applications. The American versions have been used long enough to prove their efficiency and reliability and they will now be freely available in Europe and the sterling area.

The growth of "automatic" industries in recent years has been almost too rapid to keep up with. A feature of it is the co-operation of American and British companies in the production of equipment and machines already widely used in the United States. This should ensure for this new British industry a dominant position in the European and Commonwealth markets. It is certainly good cause for satisfaction that there should be the free exchange of ideas and "know-how" between the two countries which such associations make possible. There is also every reason to expect that this influx of new ideas and new methods will of itself stimulate industry into their acceptance and use. Change is often equally a factor of the invention as well as of the need, indeed it is sometimes difficult to be precise as to which came first. The need, in broad terms, is for higher productivity: the inventor who responds to it may do so in unexpected ways which in turn open up new possibilities. But there is also a need for caution: the wastage rate in a period of rapid technological change tends to be high, and the returns can be distressingly small for many years.

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B.O.A.C. goes for Speed

In many respects, the results of the British Overseas Airways Corporation for 1955-56 are excellent. The number of passengers carried rose by 32 per cent., and the capacity ton-miles provided increased, by 21 per cent. to about 260 million. As a result, gross operating revenue was up by 16 per cent. to £42·7 million. In consequence, B.O.A.C. have wiped out the deficit accumulated largely as a consequence of the failure of the Comet 2 during earlier years. But Mr. Gerard d'Erlanger, the Corporation's chairman, is far from satisfied with the results. Despite the increase in mileage offered, he points out that the distance still fell short by 9 per cent. of what could have been provided had the Comet 4 been in operation last year. Mr. d'Erlanger is also dissatisfied with B.O.A.C's share of the traffic between this country and North America, which he believes should be in the region of 50 per cent., or almost double the corporation's share last year.

In the view of B.O.A.C., the only method of building up traffic and holding it through the 1960's is to invest quickly in the latest planes scheduled for production. Already the airline has several expensive Douglas DC7C piston-engined planes on order, representing a considerable dollar outlay, but it is said that the corporation is interested in acquiring the newer American jets, and that it will soon ask the Government to sanction the purchase of between 15 and 20 Boeing 707's at a cost of about £30 million. It would appear that the Corporation has decided that the fast, high capacity jet is the long-term answer on the highly competitive North Atlantic route. The Britannia and the Comet 4 may fill the gap for the time being, but taking a 10 to 15-year view the North Atlantic traffic can be held only by high-speed planes—such is the opinion anyway. The Comet 4 should be in service before the American jets, albeit at a lower passenger capacity. The turbo-prop Bristol Britannia has a proven speed of about 450 m.p.h., compared with the claim of 500—600 m.p.h. of the new American jets. It will also be in service before the Boeing 707 and Douglas DC8 (the latter has yet to reach the prototype stage), and being a vast improvement on the present large piston-engined planes on transatlantic service, should do much to regain some traffic in the next two or three years before the long-range jets come into operation. The short-term outlook is therefore much brighter than the long-term one.

For a number of years the prospect on Commonwealth routes is reassuring, for both the Britannia and the Comet have years of valuable service ahead of them. But on the highly competitive, prestige-bedevilled North Atlantic route the outlook for B.O.A.C in the 1960's is problematic. It will remain so until the British aircraft industry goes one better than the Boeing, the Douglas and the Convair.

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George Cohen's Outstanding Year

At a time when many kinds of steel are still scarce and the machine tool industry is having the greatest difficulty in coping with the flow of orders, it is not surprising that George Cohen, Sons and Company, Limited, continue to report steady progress. In the year ended March 31, 1956, the group increased both its turnover and its profits despite a warning from the chairman a year ago that profits might well be down owing to rising costs. In the event, the group has done better than the chairman dared to foresee.

During the year which ended last March, and in the first few months of the current year, there were three important developments in this group. First of all, Cohens acquired Dunlop and Ranken Limited, of Leeds, the largest individual merchant stockholders of steel in the country. The move thus notably reinforces George Cohen's traditional interest in merchanting. The second development has been a measure of internal re-organisation by which the parent company in the group assumes the title of the George Cohen 600 Group Limited, the present name being transferred to a new subsidiary which takes over the trading activities of the parent company. The latter becomes the controlling and financing hub of the 600 Group. The third significant development in 1956 has been the introduction of an employment security scheme which came into operation on June 1, 1956. It provides that in the event of the company having to terminate anyone's employment (on present showing a most unlikely contingency) through no fault of his own, the employee will get one week's notice for each complete year of service with the group, or wages in lieu.

It is apparent from the chairman's remarks that some of the subsidiary companies, including K. and L. Steelfounders and Engineers Limited, felt the pressure of rising costs on their profit margins in the last financial year, and it will be surprising if this pressure is not encountered during the current year. The group, like many other concerns, has given an undertaking not to increase its prices except under extreme pressure, but it is under no corresponding advantage so far as wage costs are concerned. Nevertheless, the chairman is satisfied that the record profits achieved in the last financial year can be approximately maintained over the current financial year.

ENGINEERING CONTRACTS

4—POSSESSION AND MANAGEMENT OF THE SITE

By F. H. B. Layfield

This is the fourth of a series of about ten articles being contributed by Mr. Layfield for the advice of engineers and others engaged on the preparation of engineering contracts. The third article appeared in ENGINEERING, *August* 31, 1956, *page* 265.

Many engineering contracts involve the erection of plant or the execution of works and in all such contracts possession of the site at the proper time is a feature of much importance. This fact is generally recognised in the contract in as much as it usually contains an undertaking by the employer or purchaser to give the contractor access to, and possession of, the site at the requisite times. The details of this undertaking deserve careful thought in order that the promise, once made, is both unambiguous and can be carried into effect without needless difficulty.

It is often found convenient to use the date of the engineer's order to commence operations as a point of origin. The Institution of Civil Engineers' General Conditions make use of this method by stating that " the employer will with the engineer's written order to commence the works give to the contractor possession of so much of the site as may be required to enable the contractor to commence and proceed with the construction of the works . . . " The common alternative method is to promise possession " in reasonable time." Both the methods mentioned have advantages, and yet neither is really satisfactory because each of them may lead to misunderstandings, and, in practice, they sometimes do. There can be several perfectly bona fide views on how long before works are to start it is necessary for the contractor to have possession of the site in order to ensure an efficient start. The phrase " in reasonable time " is an even more uncertain expression than that used in the Institution of Civil Engineers' General Conditions. The mere fact that the amicable relations existing between most engineers and contractors usually enable these imprecise arrangements to work harmoniously should not obscure the fact that they may sometimes lead to unnecessary friction. It is the function of the draftsman so to draw the contract as to prevent *any* misunderstandings wherever he can. It will help in this task if the engineer is able either to name the day on which possession shall be given, or to fix the date as being some specified number of days after the order to commence has been issued, or by some similar formula.

OCCUPATION BY SECTIONS

Sometimes it is convenient, or necessary, to hand over the site in parts and, once again, the object should be so to state what is proposed that it leaves the least possible room for doubt. Presumably the moment comes when the engineer must, in any event, decide upon the day on which possession of each part of the site shall be given. If he is able to see far enough ahead, it is desirable to state these dates, or the means by which they are to be ascertained, when the contract is drawn. In many cases, the contract requires the contractor to supply a programme of work. In the Institution of Civil Engineers' General Conditions this is done by stipulating that " as soon as practicable after the acceptance of his tender the contractor shall if required submit to the engineer for his approval a programme showing the order of procedure and method in which he proposes to carry out the works . . . . " Where such a programme forms part of the formal contract arrangements, it may be convenient and practicable to state when the several parts of the site shall be made available by reference to this programme.

THIRD PARTY INTERFERENCE

If no date for handing over the site is fixed, then the contractor is entitled to have possession within " a reasonable time." What constitutes " a reasonable time " must be ascertained from the detailed facts of each case. Failure by the purchaser to give possession of the site, either on the date specified, or else in a reasonable time, will render him liable to pay the contractor appropriate damages. Nor can the purchaser normally escape that liability, merely by granting a suitable extension of the time specified for the completion of the work. On the other hand, the obligation to hand over the site as and when provided in the contract does not mean that the purchaser will be liable where possession is prevented by the wrongful interference of a third party. Thus in the case of *Porter v. Tottenham Urban District Council*, the only access to a site was by a street, and the owner of the soil of the street maintained that it was not a public highway, refused to allow its use and threatened to sue for an injunction. The contractor stopped work for two months until the Council had established that the street was a public highway. The contractor was held to be unable to recover damages for the delay, because there was no obligation on the part of the purchaser to prevent or indemnify against the wrongful interference by a third party in regard to possession of the site.

LIMITS OF SITE

Once the engineer has decided when to make the site available he will wish to be sure as to what precisely is to be handed over. Moreover, the purchaser owes a number of important duties to persons coming on to the site, and this is another reason why it is important to establish exactly where the site begins and ends. It is up to the ingenuity of the draftsman to define the site accurately in words, but, of course, he cannot do this properly if he is not told by the engineer in clear terms where the site is and what are its boundaries. There is usually only one way to provide this description in a fully effective way and that is by reference to a map or plan. If that map or plan can be made part of the contract, so much the better. Even when this cannot be done, a map or plan should still be available to provide a guide, as, for example, where the completion of an appropriate blank in a printed form is required. On some of these printed forms, the site is defined mainly by saying that it is the place where the contract work is to be carried out. Unless there is to be found elsewhere in the contract a clear statement defining and limiting the place where the work is to be done, such a definition is, for many purposes, no definition at all. Time and again, a map or plan will be found to be the easiest and quickest way of supplying the required data.

LIABILITY FOR ACCIDENTS

From the moment that plant and materials begin to arrive on the site, or work commences there, the possibility of accidents becomes a matter for consideration. In the first place, there is the likelihood of accidents causing injury to people or their property and, secondly, of damage to the works themselves. It is in the nature of engineering operations that these hazards are very real, and the engineer will find it well worth while to consider with unusual care those parts of the contract which concern liability for such happenings on the site. It is a general principle of law that a person is liable for his own torts and for those committed by his servants. On the other hand, a man is not, generally, responsible for the torts committed by an independent contractor. The result is that an employer cannot, as a general rule, have the results of a contractor's torts visited upon him. Yet there are important exceptions to this rule. For example, as Lord Justice Romer has said, whenever the work " of its very nature involves a risk of damage to a third party," the purchaser will be liable for any damage which ensues. In such instances, the purchaser owes a duty to others though he may, in the words of Lord Blackburn, " bargain with the contractor that he [the contractor] shall perform the duty and stipulate for an indemnity from him if it is not performed but he cannot thereby relieve himself from liability to those injured by the failure to perform ".

Since, in many instances, the liability cannot be avoided, indemnity clauses in the contract are of real importance to the purchaser. For the sake of clarity and effectiveness, it is desirable to keep separate the indemnity dealing with damage to persons and property from all other forms of indemnity, as is done in the Institution of Civil Engineers' General Conditions. This promise is usually a mutual one, in that the contractor indemnifies the purchaser against claims arising from matters under his control, and the purchaser responds in regard to matters under his control or for which he, the purchaser, is peculiarly responsible. If an indemnity is taken from a contractor and a claim affecting it is made, the contractor is acutely interested since he may expect to foot any bill which results. It is, therefore, both sensible and helpful to provide, not only that the contractor shall be notified promptly of any relevant claim, but also that he be entitled, at his own expense, to take over negotiations for the settlement of any such claim, should he so desire.

REASONABLE PRECAUTIONS

Clearly it is better to avoid legal disputes and to prevent accidents wherever possible. Nowadays, these very frequently arise from neglect to observe reasonable established precautions. Steps to avoid such neglect must naturally depend to a marked degree upon executive action and supervision. Yet some assistance can be afforded by the contract, in that certain precautions can be set out therein, and explicit mention made of regulations which should be observed. The draftsman is not always in a position to perform this task adequately, however, unless properly instructed by the engineer.

The other main type of site hazard is that of damage to the works themselves. The contract usually states who is to bear the risk if such damage occurs; very often it is provided that the contractor shall bear full responsibility for any damage, except in regard to certain " excepted risks." If the purchaser assumes responsibility for any kind of loss the clause defining this should be especially carefully drawn. Once a party has clearly undertaken to assume the liability for a particular risk he may then be liable even though the loss occurred through the negligence of the other party. This was what happened in the recent case of *Archdale (James) & Co., Ltd. v. Comservices, Ltd.* The employer in that case had undertaken to bear the risk of loss due to fire. In the event, a fire occurred which was caused by the negligence of the contractor's servants. The employer was not able to recover because he had given an unqualified undertaking to bear loss due to fire.

Regardless of who is to bear the risk of loss, it is usual to require that it shall be covered by insurance. This is a singularly useless provision should a loss arise and it be found that the insurance has not, in fact, been effected. It is therefore important, as in the transport of plant mentioned in the previous article, to couple with the insurance requirement an obligation to produce the policy and premium receipts. These documents should be produced at a specified time, if possible *before* the risk involved can arise. It may also be desirable, in some circumstances, to provide that in default,

the purchaser may effect the requisite insurance and recover the appropriate sum from the contractor.

Finally, it should be remembered that the contract ought to set out proper arrangements for the liabilities which will arise during the maintenance period. In a great many cases, these will be identical with those which rule the period prior to completion. In such instances, the contract will expressly state that this is to be so. But it should not be taken for granted that conditions prevailing in the maintenance period will be such that obligations prior to completion should in all respects be carried forward. Here, as in so many other instances, the draftsman looks to the engineer to indicate what practical arrangements will be best.

MEASURING FLOW IN PIPELINES BY AN AEROFOIL

METERING LOSSES REDUCED

By C. E. R. Sams, F.C.G.I., M.I.MECH.E.

The classical methods of flow measurement in pipelines by means of orifice plates or Venturi tubes, involving substantial head losses where high flows are in question, are responsible for quite appreciable increases in fuel costs and consumption. In 1948, for example, a water company was spending over £5,000 a year on coal solely to make good the losses due to the differential pressure metering in their various pipelines. In the hope of reducing these costs the Board asked the author in 1950 whether a more economical method of flow metering could be devised. As a result the aerofoil flow meter has been developed, a unit which has not only had the desired effect of reducing the losses dramatically, but which also has the advantages that the installation cost is low, that it can be used anywhere in a pipe system, that it can be used for measuring widely varying flows, and that it can be readily dismantled for cleaning without stopping the plant.

The following example will make clear the type of savings that can be expected from the use of the aerofoil flow-measuring unit. The flow of cooling water in a 40 in. diameter main was 4 million gallons per hour; to measure this quantity, an orifice plate was fitted in the main, giving a differential pressure of 24 in. W.G. This caused a power loss of 80 million ft.-lb. per hour. The same measurement can be made with an aerofoil unit causing a pressure loss of only 0·25 in. W.G., with a loss of power of about 800,000 ft.-lb. per hour.

The aerofoil flow-measuring unit is, like the older methods of flow metering, based on the measurement of the pressure difference between an upstream tapping in a region of undisturbed flow and a downstream tapping on the unit itself; but the latter, taking the form of an aerofoil small in relation to the cross-section of the pipe, introduces very little flow disturbance in the main body of the fluid. The downstream tapping is taken at the surface of the aerofoil itself at any suitable point, but generally speaking at the point on the upper surface where the local lifting force attains its maximum value, and hence the differential pressure is at a suitable value, such as 5 in. W.G., with a loss of pressure of about 0·35 in. W.G.; or for gas, 0·5 in. W.G. with a loss of 0·03 in.

The aerofoil unit is suitable for a 2 in. diameter pipe or a 60 in. diameter main, the actual size being chosen to suit the conditions. Most of the development work has been carried out in large full-scale installations, and an aerofoil of about 3 in. chord, 4 in. span and 1½ in. thickness, has been used in, for instance, a 30 in. diameter main. Fig. 1 shows a cross-section through a typical aerofoil unit, which is drilled for three alternative pressure tappings, any one of which can be used, the others being plugged, to give a suitable range of differential pressure. The aerofoil is mounted on a hollow spindle, the bore of which is connected at the one end to the aerofoil surface tapping and at its outer end to one side of the differential-pressure element.

The aerofoil can be rotated about the spindle to vary the angle of attack relative to the fluid stream, from 0 to 60 deg., thus giving an additional means for adjusting the pressure differential range. A further adjustment is possible by shifting the aerofoil laterally from the centre of the pipe towards the wall, thus decreasing the velocity of the fluid acting on the unit. Thus it is possible to adjust the pressure differential for a given flow over a wide range—and, conversely, it is possible to measure with the same aerofoil unit in the same pipeline flow ratios varying by as much as 1 to 120.

FULL-SCALE DEVELOPMENT TRIALS

Since 1950 a series of full-scale trials of the aerofoil flow-measuring unit installed in pipelines carrying water, steam, coal gas, producer gas, coke-oven gas and compressed air have been carried out. Wind tunnel tests to determine the pressure distribution round the aerofoil were carried out in a wind tunnel. From some 9,000 test results, the comparative curves of head loss for the orifice plate, the Venturi tube and the aerofoil unit have been plotted and are reproduced in Fig. 2.

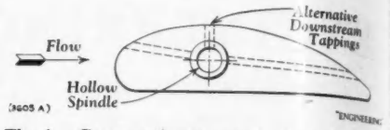

Fig. 1. Cross-section through typical aerofoil unit, drilled for three alternative pressure tappings, and mounted on a hollow spindle which connects the tapping in use to the pressure gauge.

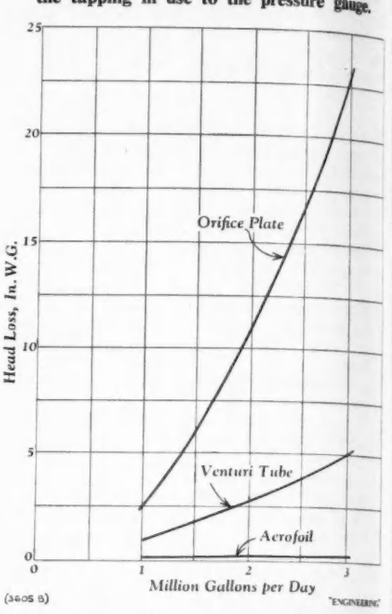

Fig. 2 Comparative curves of head loss for the orifice plate, the Venturi tube, and the aerofoil unit.

The development of the aerofoil unit, the installation of which is very simple, has been almost entirely empirical, and it has been found in practice that the unit can be installed anywhere in the pipeline—for instance, immediately after a right-angle bend—without upsetting the square-root relation of the flow rate to differential head. Fig. 3 shows how closely the actual test results with an aerofoil unit conform to the theoretical square-root law; in this instance no deviation between the actual and theoretical curves has been obtained. It is thus a very simple matter to calibrate the unit, since it is only necessary to obtain one, or at most two, points in order to derive the shape of the calibration curve. Where great accuracy is not required, a straight-line approximation can be adopted and equally-spaced charts can then be used for recording the flow.

Compared with a Venturi tube or an orifice

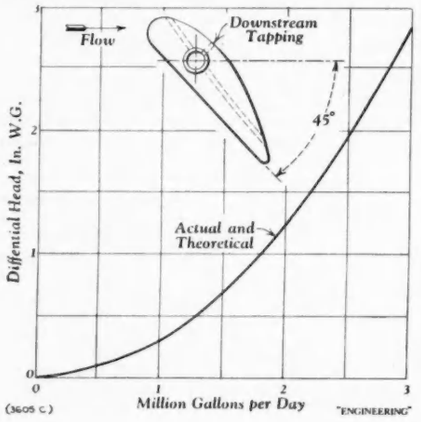

Fig. 3 (left) Comparison of typical test curve of differential head plotted against flow obtained with an aerofoil unit, and the theoretical "square-root law" curve.

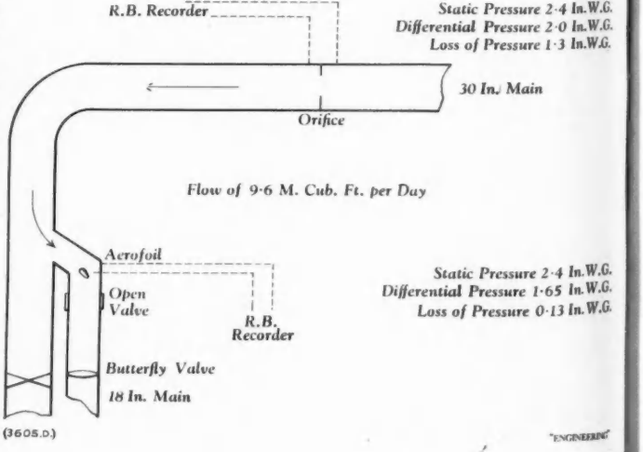

Fig. 4 (right) A full scale trial arrangement of an aerofoil unit and an orifice plate installed for comparison in a gas main carrying 9·6 million cub. ft. a day.

plate, the aerofoil unit offers a great advantage for such purposes as measuring the flow through a coke-oven gas main. When the aerofoil becomes coated with tar and, consequently, becomes inaccurate, it can be taken out, cleaned and replaced in a few minutes without stopping the plant, since it can easily be put in and taken out through a 2 in. hole in the main.

The diagram, Fig. 4 on the previous page shows one of the full-scale trial arrangements of an aerofoil unit in a gas main carrying 9·6 million cub. ft. a day, in comparison with an orifice plate. The latter is installed in a straight run of the 30 in. main itself, whereas the aerofoil unit is installed at a bend in the 18 in. branch main. The pressure loss caused by the orifice plate, 1·3 in. W.G., is ten times that caused by the aerofoil unit.

For measuring corrosive fluids, the aerofoil could be made in porcelain; and, in refractory material, it could be used in gases at high temperature. The initial accuracy is maintained since little erosion or corrosion is likely to occur, such as would in time affect a square-edged orifice plate.

Further trials to be carried out on the aerofoil unit this year include the metering of sewage and tests in the Buxton wind tunnel to determine its suitability for metering the ventilation in coal mines. The author regards this latter investigation as one of great importance because, up to the present, the usual means of measuring ventilation in coal mines has been by a portable anemometer giving a spot reading only. In the event of disaster there may therefore be no record available of the state of the ventilation. The aerofoil unit, it is believed, will provide a means for measuring the ventilation continuously and for recording it remotely at the surface and at the deputy's cabin at the pit bottom. Extensive trials are now being carried out on oil.

The aerofoil unit should be calibrated on site to avoid any unknown disturbing factor, and a pitot tube traverse is one simple method of calibration; or in the case of an aerofoil unit replacing a Venturi tube or orifice plate, the calibration could be by these latter; after calibration they would be removed.

As a result of the satisfactory trials that have already been carried out, orders for the installation of the aerofoil flow measuring unit have been placed by a number of important concerns, and in many cases the installation would be in a position at which it would be impossible for a Venturi or orifice plate to function satisfactorily.

At the present day, there are 35 million tons of coal wasted every year, estimated at one-sixth of the total production of coal in the United Kingdom. A great part of this could be saved by more economical use. The aerofoil flow meter is one means for reducing the waste of coal.

* * *

To make and exploit the aerofoil flow meter described in the article above, a private company, the Aerofoil Flow Metering Company Limited, has been formed. The company's offices are at Cross Keys House, 56, Bishopsgate, London, E.C.2.

Engineering Papers at the British Association Meeting

Three papers presented to the Engineering Section of the British Association meeting at Sheffield are published in this issue of ENGINEERING. *Other papers delivered to the Section were on the following subjects:—"A review of boiling heat transfer with particular reference to unstable flow"; "Measurements of the velocity and deposit patterns of dust clouds"; "Solid solutions in iron"; "High temperature alloys"; "Improving cutting tool performance by practical research"; "The orthogonal cutting of a work-hardening material"; "The mechanics of the metal cutting process"; "Automation—the historical and scientific background"; and "Problems and achievements in coal face mechanisation".*

POWDER METALLURGY REVIEWED*

By L. D. Brownlee, B.SC., A.INST.P.

The art of powder metallurgy reaches back many thousands of years. As long ago as 3,000 B.C. the Egyptians were reducing iron oxide with charcoal to produce sponge iron which was hammered and wrought into a great variety of articles. It is, however, during the present century, commencing with the production of ductile tungsten-filament wire by Coolidge, and the development of cemented carbides in Germany during the period 1920-1930, that the foundations of modern practice have been laid. Powder metallurgy to-day covers an extremely wide field, both as applied to the production of basic metals such as tungsten, molybdenum and tantalum, and in the manufacture of finished products such as tool tips, magnets and sintered iron parts. It is helpful in surveying this field to consider why powder metallurgy is used at all, in preference to what we may call classical metallurgy. We then find that, in general, there are three basic reasons for employing powder metallurgy. In any one case, one or more of these reasons may exist, but always at least one is involved.

Melting Points of the Metals Involved.—In the manufacture of the refractory metals such as tungsten, molybdenum and tantalum, the melting points of the metals are so high that the electric arc is the only method of melting them, and it is virtually impossible to find a suitable refractory to contain them. By pressing the finely divided metal powders into suitable bars, these can be heated to a temperature well below their melting point, preferably by passage of an electric current through the bar itself. Under these conditions the grains sinter together and a solid metal bar is produced which can be hot worked into rods or rolled into sheet.

Achievement of Special Metallurgical Structures.—By using powder metallurgy techniques, metals can be obtained having physical properties and structures unattainable by normal metallurgical processes. Obvious examples are the porous filters and the self-lubricating bearings. These consist of metals having a controlled interconnected porosity, and this structure can only be attained by powder metallurgy. Switch contacts are made from alloys of copper and tungsten or silver and tungsten. In these cases, since there is no solubility of one component of the alloy in the other, and such a great difference in the melting points and densities of the components, the alloys cannot be made by melting.

It is often possible to control the grain size of metals and alloys made by powder metallurgy to a much greater extent than when they are made by melting and casting. In general, the metal powders have an extremely fine grain size, and this grain size is maintained at the temperature at which they will sinter. There is usually a range of temperature between the minimum sintering temperature and the melting point, and if the metal is heated through this range, grain growth takes place. Hence, by controlling the sintering temperature, the grain size of the metal can be controlled. The unique properties of cemented carbides stem from the fact that they consist of a mass of hard particles of carbide set in a matrix of tough ductile cobalt. However, tungsten carbide dissociates on heating to form the lower carbide W_2C plus carbon. This means that melting techniques are not possible, quite apart from the high temperatures involved.

Economic Considerations.—If large quantities of identical parts are required, finished to very close tolerances, in iron, steel, copper, brass, etc., it is a very attractive proposition to press metal powder in a mould to the required shape, and sinter this to form the finished article. Though metal powders are relatively costly, and moulds and presses are expensive, yet in cases where really large quantities of a single component are required, powder metallurgy will compete purely on an economic basis.

BASIC TECHNIQUES

In the first place, suitable metal powders have to be prepared. These powders must have a closely controlled grain size, since this affects both the pressing characteristics of the powder and the properties of the finished article. Usually the powders are prepared by reduction of the metallic oxide. If more than one kind of metal powder is to be used, the powders are thoroughly mixed by ball milling them together, usually for a period of several days. The powders are then pressed in a mould at such a pressure that the resulting compact can be handled. In some cases a lubricant such as paraffin wax is added to the powder to make it bond more easily in pressing. The pressed blocks are then heat treated to cause the material to fuse together or "sinter." This is the fundamental operation in powder metallurgy. It transforms the mass of powder into a dense, metallic body, but at no stage does the whole mass become molten. This is the basic difference between a sintered body made by powder metallurgy and one made by normal casting methods.

There are two distinct kinds of sintering mechanism. In cases where a single metal is being sintered, such as iron or copper, the sintering mechanism is a gradual diffusion at the boundaries between individual powder particles. This process usually commences at a temperature which is about 90 to 95 per cent. of the melting point of the metal. This atomic diffusion continues and gradually the pores in the pressed powder are filled up and the material becomes dense. At the same time a shrinkage occurs in the overall dimensions of the pressed body. Increasing the sintering temperature increases the rate at which maximum density is approached. During the shrinkage recrystallisation usually occurs and an increase in temperature will cause an increase in grain size.

The control of the shrinkage, which is affected by the pressing technique, the grain size of the powder and the sintering temperature, is perhaps the most difficult and important process in the manufacture of articles by powder metallurgy, since the production of finished parts to very close dimensional tolerances is one of the chief advantages of this method. A similar process takes place in the sintering of alloys made from two or more metals, if no liquid phase is formed. Solid solutions and intermetallic compounds can all be formed by this mechanism. The amount of porosity in the finished article can be controlled by varying particle size, sintering time and sintering temperature, and, of course, this property is made use of in the manufacture of porous bearings and metal filters. In certain systems such as that of tungsten carbide-cobalt, a low melting point eutectic may be formed. In this case, the sintering temperature is above the eutectic temperature and some liquid phase is formed during sintering. This liquid phase acts as a binder and cements the hard particles together, resulting in a dense homogeneous body free from pores. If too much liquid phase is formed, the body will distort and lose shape and, of course, this must be avoided. The sintering process must be carried out in a non-oxidising atmosphere and hence hydrogen furnaces or vacuum furnaces are used for sintering.

MOLYBDENUM

Let us now consider some typical manufacturing processes and see how these considerations apply. A good example of a refractory metal is molybdenum which is used in great quantities in the form of sheet and wire in the thermionic-valve industries. The melting point of molybdenum is about 2,600 deg. C., and while it can be melted on a water-cooled copper hearth in an arc furnace, the resulting ingot has a very coarse grain size and will not stand hot working. For this reason, molybdenum is produced by powder metallurgy.

The raw material is molybdenite (MoS) which is crushed and fed into a revolving inclined retort heated to about 1,050 deg. C. An air blast is fed into the retort and the sulphide is converted to molybdenum oxide. This is highly volatile at this temperature and sublimes off and is collected in suitable dust traps. The molybdenum oxide is then reduced by hydrogen to metal powder at about 1,050 deg. C. The metal powder is pressed into bars at a pressure of about 25 tons per sq. in. If the bars are to be used for making wire, long bars of square section 1 in. × 1 in. × 18 in. are made. For sheet, flat bars are pressed $\frac{3}{4}$ in. × $\frac{1}{2}$ in. × 18 in.

* Paper entitled "Powder Metallurgy" read before Section G of the British Association at Sheffield on Friday, August 31.

These bars are pre-sintered by heating to 1,200 deg. C. in a continuous hydrogen furnace. This gives them sufficient mechanical strength for handling. Final sintering is carried out by direct resistance heating of the bars in a hydrogen furnace to a temperature in excess of 2,000 deg. C., but still well below the melting point of molybdenum. The sintered bars can then be hot swaged or hot hammered to produce rods or slabs. Swaging is continued until the rods have a diameter of about $\frac{1}{4}$ in., when they can be cold-drawn into wire. The slabs are hot rolled down to 0·06 in., starting at 1,100 deg. C. and finishing at 800 deg. C. From this size they can be cold rolled to finished sheets. Reheating and annealing are carried out in hydrogen-atmosphere furnaces.

HARD METALS

In the second group of materials made by powder metallurgy are those having special metallurgical structures; probably the most interesting are the so-called hard metals or cemented carbides. These materials have been intensively developed during the last 25 years and are now firmly established as high performance cutting tools and wear-resisting materials. They are used widely for drawing and stamping dies, coal and rock drills, and, of course, virtually all high-speed machining operations depend on carbide tools. While the method of manufacture has not been basically changed for 25 years, the metallurgy of these materials has been extensively studied recently, and this has led to a vast improvement in their quality.

The cemented carbides can be divided into two main groups. The first group consists of tungsten carbide bonded with cobalt. These are used for machining cast iron, non-ferrous metals, and non-metallic materials, and also as wear resisting materials. When used for machining steel, however, they wear badly, due to cratering of the cutting edge and the performance is very poor. For machining steel, the second group of carbides has been developed. This group consists of tungsten carbide with additions of titanium and tantalum carbides, the mixed carbides being again bonded with cobalt.

The effect of these additions is to increase the resistance of the material to cratering and to increase the hot hardness of the alloy. A typical range of compositions is shown in Table I. Thus it will be

TABLE I.—*Range of Percentage Compositions of Cemented Carbides*

Cobalt	Tungsten carbide	Titanium carbide	Tantalum carbide
6·0	94·0		
8·0	92·0		
10·0	90·0		
12·0	88·0		
7·0	68·0	25·0	
6·0	78·0	16·0	
9·0	78·0	9·0	4·0
9·0	82·0	5·0	4·0

seen that the cobalt content ranges from 6 to 12 per cent., and additions of carbides other than tungsten carbide can go up to 25 per cent., but the main ingredient of all these is tungsten carbide. This is made by mixing together tungsten-metal powder and lampblack, or graphite, and heating the mixed powders in a carburising furnace. The minimum temperature for successful carburisation is 1,350 deg. C. Above 1,500 deg. C. grain growth of the tungsten carbide occurs. The carbide after heating is in the form of a fritted powder which is easily broken down by ball milling. Cobalt metal powder can be obtained from the reduction of cobalt oxide at 700 deg. C. in a hydrogen furnace. Titanium and tantalum carbides are produced by the reduction of the oxides by carbon in a vacuum furnace. High temperatures of the order of 2,000 deg. C. are required.

For the second group containing tantalum and titanium carbides as well as tungsten carbide it is usual to preheat a mixture of the carbides to form a solid solution. TaC and TiC are mutually soluble and they both take into solution a large amount of tungsten carbide. By mixing the carbides in the right proportions and heating them in hydrogen or in vacuum a "mixed crystal" or solid solution is formed. This is still in the form of a fritted powder and can be broken down by ball milling. The next stage is to mix the cobalt, tungsten carbide, and, if required, the mixed crystals in the required proportions and mill the powders together for a period of 2 to 3 days. On the correct milling technique depends the grain size of the milled powders and this, in turn, affects their characteristics when pressed. The powders are milled in a cylindrical mill containing balls. The mills are lined with stainless steel or "Stellite." Since the balls are subject to severe wear they are made of hard metal. A liquid such as white spirits is usually added to the mill to prevent oxidation of the powders and to assist in the grinding action. After milling, this liquid is filtered off and the powders are heated in hydrogen to distil off the liquids. The powders are then pressed in moulds at pressures of 5 to 15 tons per sq. in. In some cases a lubricant such as paraffin wax dissolved in carbon tetrachloride is added to the powder to aid in pressing. It is better if the powders can be directly pressed into finished shapes at this stage. For complicated shapes, however, it is sometimes necessary to press the powder into large blocks. The blocks are then heated to about 900 deg. C. to drive off the wax and cause the powder to frit together slightly. This gives the block sufficient strength to be handled and it can be cut up and machined to any desired shape.

Sintering is the final heat treatment and is carried out in hydrogen or vacuum furnaces at temperatures of 1,350 to 1,500 deg. C. Sintering furnaces can be either continuous-type hydrogen furnaces using a molybdenum winding; or high-vacuum high-frequency induction batch-type furnaces. The sintering operation results in a large shrinkage of the compacts, of the order of 20 per cent. on the linear dimensions and a very hard dense metal is obtained. It is perhaps worthwhile to consider briefly what takes place in the sintering process. Tungsten carbide and cobalt form a eutectic at about 1,275 deg. C., so at this temperature a small amount of liquid phase is formed, and this "wets" the remaining grains and begins to draw them together. As the temperature is increased, more liquid phase is formed and some tungsten carbide is dissolved in the cobalt. The more cobalt there is present in the mix, the more liquid phase there will be at a given temperature. Since there must only be sufficient liquid phase formed to ensure complete sintering, i.e. complete shrinkage and densification, then the greater the amount of cobalt, the lower will be the sintering temperature. On cooling, some tungsten carbide will be precipitated from the cobalt, and this tends to form a continuous network of tungsten-carbide grains with almost pure cobalt in the interstices.

It has been mentioned earlier that if titanium or tantalum carbides are to be used, they are added in the form of a solid solution of tungsten carbide in the titanium-tantalum carbide. This solid solution is formed at a higher temperature than the sintering temperature so, if those carbides are to be used, during the sintering only a slight re-precipitation of WC takes place. For any given composition, increasing the sintering temperature above the minimum necessary for complete sintering, causes grain growth of the tungsten carbide, and this leads to brittleness of the carbide. Another important factor is the carbon content of the sintered material. Tungsten carbide has a theoretical carbon content of 6·13 per cent., but in practice the carbon content can vary above and below this limit. If the carbon content is too low, a brittle compound, Co_3W_3C, tends to be formed and this makes the carbide brittle. If it is too high, free carbon tends to be present and this leads to a loss in hardness. The sintering conditions must be carefully chosen to give the correct carbon content in the finished carbide, and avoid either of these pitfalls.

The hardness of these carbides depends on both the grain size of the carbides and on the cobalt content. An increase in cobalt content decreases the hardness for a given grain size, and a decrease in grain size of the carbides increases the hardness. For any given cobalt content, the addition of mixed crystals to the tungsten carbide will increase the hardness very slightly. The transverse rupture strength increases rapidly with increase in cobalt content and is greater for coarse-grained carbide than for fine-grained carbide.

SINTERED IRON

A typical example of the use of powder metallurgy on economic grounds is afforded by considering the manufacture of parts from sintered-iron powder. The metallurgy of this process is quite straightforward. Iron powder can be produced having a high purity and small particle size by several different methods which we shall consider later. The powder can be compacted in moulds and sintered in a hydrogen furnace at temperatures between 1,150 and 1,350 deg. C. The physical properties of the finished product depend upon several factors such as the grain size of the powder, the pressure applied in compacting, and the time and temperature of sintering. The mechanical properties improve as the porosity decreases, but they are always less than that of the conventional machined components. Thus the field of sintered-iron products is limited to that portion where good mechanical properties are not essential. Since, however, the sintered parts can be produced to very close tolerances, and no machining is necessary, the actual cost of each part can be very low. The dies for pressing the powder can be very expensive—from £100 to £1,000 or more—but they have a long life and where large quantities of a given part are required, the overall cost per item can be very low.

Typical parts produced in this way are: cams for light duty, small lightly stressed gears, bushes, valve guides, levers, rifle parts, pedal-cycle sprockets, roller-bearing cages, etc. Iron powder suitable for pressing and sintering can be made by several different processes. Iron oxide may be reduced by charcoal or a gas such as hydrogen, "cracked" ammonia, or carbon monoxide. This gives a good iron powder which is ductile and of a fine grain size. Electrolytic methods, such as the electrolysis of ferrous chloride can be used. In this case, a stainless steel sheet is used as anode and iron is deposited in the form of a brittle mass which can be broken up by ball milling and the powder can then be cleaned and annealed in hydrogen. Other methods include the carbonyl method, mechanical disintegration methods, and the atomisation of molten iron by pouring it on to a water jet. All these methods give iron powder suitable for different uses.

Carbonyl iron, which is costly, is used in the manufacture of magnetic materials. Electrolytic iron powder is used for magnets and some components. Mechanically reduced and atomised powders are used in Germany, while in this country the tendency is to use electrolytic powder or powder reduced from sponge iron. A typical process for manufacturing sintered iron is as follows. First the iron powder is cleaned in hydrogen for say 20 minutes at 1,050 deg. C. This reduces any oxide films on the surface of the powder particles and the caked powder is broken up and sieved to obtain the required particle size. A bond, such as 1 per cent. stearic acid, can be added to aid in pressing and if a carbon steel is required, carbon in the form of fine graphite powder can also be added. The powder is compacted at pressures of the order of 25 to 50 tons per sq. in. The design of the die is very critical and must be arranged so that the powder can flow easily under the punch. Tool-steel dies should produce 25,000 to 50,000 components while hard-metal dies will have a life of up to 500,000 parts.

Sintering is carried out in continuous furnaces in an atmosphere of cracked ammonia or hydrogen. To obtain maximum density, it is sometimes advantageous to re-press the compacts after sintering and then sinter them a second time. This, while improving the physical properties of the material, puts up the total cost of the process. In some cases, where very exact dimensions are required, the parts, after sintering when they are slightly oversize, are pressed cold in a die of the exact finished size. Sintered alloy steels can be produced by methods similar to those outlined for sintered iron, but in general the process is more difficult.

SOME MODERN DEVELOPMENTS

Powder metallurgy has opened up methods for studying a wide range of new materials. All the stable carbides, borides and silicides of metals can be studied by these methods. The high melting point borides of the transition metals of the fourth to sixth groups of the Periodic Table form most promising high-temperature materials. Nickel-bonded chromium borides are very good up to say 950 deg. C., while zirconium boride is stable at very high temperatures. Among the silicides, molybdenum silicide, $MoSi_2$, can be made by powder metallurgy and it forms an extremely good heating element, being stable up to 1,700 deg. C.

Beryllium is also being fabricated by a powder-metallurgy process. Although it has a low melting point, 1,315 deg. C., and can be cast quite successfully in a vacuum induction furnace, the ingots produced are not easily worked into a useable form. These ingots can be turned down into chips and further reduced by ball milling in an inert atmosphere. The fine grained powder produced may be pressed up into compacts and sintered at about 1,100 deg. C. The resulting metal will have a fine grain structure and good mechanical properties. It is possible to press the powder directly into the required shapes so that sintering produces the completed article, or, alternatively, sintered billets may be produced which can then be fabricated by rolling, extruding, swaging, or any other normal metal-working technique, into any desired form.

This paper has been a necessarily brief survey of the field of powder metallurgy, but it shows that the science is now firmly established, and much has been accomplished. At the same time, new developments are occurring rapidly and there is no doubt that there is a wide future for powder metallurgy.

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CONTROL OF FLUX WAVEFORM IN TRACING HYSTERESIS LOOPS*

VARIABLE INSTANTANEOUS TRACING RATE

By R. G. George, B.SC. (ENG.)

Summary.—The apparatus described in this paper is used to trace on the C.R.O. the hysteresis loops of small diameter ring specimens of magnetic ferrites which have "rectangular" loops. The special feature of this equipment is the provision of means for varying the instantaneous rate of tracing of the loop in any predetermined manner throughout the cycle. This is accomplished by means of negative feedback from the specimen, an amplifier being used to control the flux waveform so that it is a reproduction of a voltage waveform which periodically repeats at a frequency in the range 100 to 15,000 cycles per sec. Methods of producing suitable non-sinsuoidal control voltages are also described.

The tracing of a static hysteresis loop by the conventional method of obtaining the deflection of a galvanometer connected to a secondary winding on the specimen when the magnetising current in the primary winding is changed, is relatively simple but fairly tedious. The process is speeded up if the galvanometer is not used ballistically, but is instead made to read flux linkages directly by having a low circuit resistance. When dealing with small specimens, the increased sensitivity is an advantage.

Various automatic hysteresis loop plotters[1,2,3,4] have been designed to trace out static loops at a rate of one cycle in several minutes. These incorporate some form of servo-driven pen recorder with electrical or electro-mechanical integration of the secondary winding voltage. The servo-amplifiers used are generally galvanometer and photocell systems which have an inherently high gain. Completely electronic amplified integration[5] is an alternative to the optical system of amplification.

The automatic system plots the loop in less time than the simple galvanometer method and has the advantage of presenting a ready drawn graph on appropriately scaled paper. However, correction of errors due to drift, and calibration, may consume far more time than the actual plotting.

The trace of a static hysteresis loop conveys considerable information about the material, but when the material is subjected to alternating current magnetisation, effects become noticeable which are not shown in the static loop. These are mainly due to the demagnetising effect of eddy currents. It is for this reason that a record of the a.c. hysteresis loop is essential when estimates of the dynamic performance of magnetic materials are required.

To display dynamic hysteresis loops [1,5,6,7], the usual systems employ the oscilloscope to give visual indication, and are similar in supplying magnetising current from a low-impedance source of sinusoidal voltage. The voltage across a low resistance carrying this current is amplified to deflect the oscilloscope trace along the X-axis, and the voltage across a capacitor, which is in series with a high resistance and the secondary winding, is amplified to provide Y-axis deflection. Provided that the current in the secondary winding is small enough to have negligible demagnetising effect, and the time-constant of the integrating resistor and capacitor is large compared with the time of one cycle, then the input to the X-axis amplifier is proportional to the instantaneous value of applied m.m.f., and the input to the Y-axis amplifier is proportional to the instantaneous value of flux in the specimen. In addition, to ensure that the displayed trace is the true hysteresis loop, the two amplifiers must have constant gains and zero phase shifts over the range of frequencies embracing all the components of both the m.m.f. waveform and the flux waveform. These may range from 1 to 10,000 cycles per sec. for a fundamental frequency of 50 cycles per sec. Theoretically the frequency response should extend down to zero or direct current.

An interesting system of automatic recording of the dynamic loop by a pen recorder has been described by Kittl.[8] This uses a method of simultaneous sampling of the m.m.f. waveform and the secondary voltage at a particular instant in the supply frequency cycle. The sampling amplifiers are electronically gated to measure during a period of about 2 μs. Their outputs are direct-current voltages proportional to the sampled voltages. A further electronic integrator can be switched in to give an output corresponding to the flux waveform in the specimen. The phasing of the instant of sampling is slowly varied by a motor driven phase-changer. The reference voltage and magnetising current source are provided by a three-phase generator. Operation may be at any frequency in the range 50 to 1,000 cycles per sec. The maximum time to trace through one complete cycle is limited to 10 minutes. Over longer periods, drift in the integrator becomes significant. The instrument has been used to trace loops for rectangular loop materials.

The present hysteresis loop tracer is similar to those described previously in its method of displaying the values of flux and applied m.m.f., but differs in the respect of supplying magnetising current from a feedback controlled amplifier. The use of negative feedback to produce substantially sinusoidal flux changes in the specimen has been described in literature.[11] The possibility of using feedback to control non-sinusoidal flux changes has also been mentioned.[12]

LOOP TRACER REQUIREMENTS

The ferrite material known as Ferroxcube type D1 has a rectangular hysteresis loop. It has a nominal peak flux density of 0·225 Wb per sq. m. with an applied field of 400 AT per m. The apparatus to be described was designed to operate with rings of this material of 8 mm. diameter. For this size of specimen, the figures quoted correspond to an enclosed flux of 4×10^{-7} Wb, attained with a magnetisation of 9·1 AT.

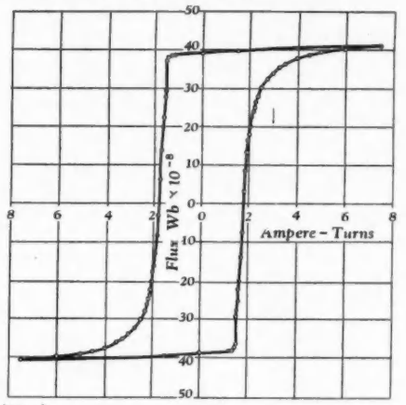

Fig. 1 "Rectangular" hysteresis loop for ferrite material.

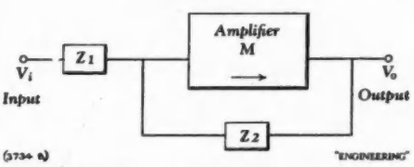

Fig. 2 Application of negative feedback.

In order to plot a static hysteresis loop, a secondary winding of 150 turns was wound on to one of these ring cores. The deflection at 1 metre scale distance was 1·8 cm. for reversal of the peak flux when using the most sensitive galvanometer available. It was possible, in spite of this small deflection, to plot accurately the hysteresis loop shown in Fig. 1 when using a scale having 40 divisions to the inch placed more than 2 metres from the galvanometer.

Investigation into the behaviour of these ferrite cores under the various current pulses occurring in magnetic core shifting registers led to the need for the display of the alternating current hysteresis loops. The standard method described was used, but was not found to be capable of reproducing test conditions satisfactorily for the following reasons. If a sinusoidal voltage is applied to the magnetising winding (which consisted of 100 turns in this case), the resulting induced e.m.f. is far from sinusoidal. This is due to the extremely low self-inductance of the winding, the winding resistance (and source impedance) being greater than the reactance, except for the short period during which the flux reverses. The insertion of a high value of series resistance to produce sinusoidal current was not very effective. The effect of the induced e.m.f., which was to maintain the current constant during the period of flux change, could be made negligible at 50 cycles per sec. by using a value of resistance of 1,000 ohms. The supply voltage was then 60 volts r.m.s. Since both the values of resistance and voltage are proportional to frequency, this method of control was very limited in its use. Thus to obtain either sinusoidal induced e.m.f. or magnetising current some form of controlling amplifier utilising negative feedback had to be used.

Control of the magnetising current in order to give it a sinusoidal form was found to be of little value since the time of the flux reversal amounted to about 4 per cent. of the duration of the cycle when the amplitude of the magnetising current was large, while a reduction in the amplitude gave much slower reversals. This effect masked any changes in the loop with frequency. Moreover, under normal conditions of operation the m.m.f. applied to the magnetic cores is never sinusoidal. In view of this, this method of controlling the supply was abandoned.

In order to control the induced e.m.f., it would be necessary to provide a controlling device giving an output proportional to frequency if constant amplitude of flux change was desired. This led to the idea of controlling the flux amplitude directly. In the normal operation of these cores, the flux changes are generally non-sinusoidal and so the apparatus had to be capable of producing suitable non-sinusoidal flux changes, as well as sinusoidal changes for purposes of comparison with other core materials.

The apparatus had to be designed to control the flux in the specimen with as little as 13 mV r.m.s. for maximum amplitude at 50 cycles per sec. across the 150-turn secondary winding, and as much as 30 volts peak during a reversal occupying less than 4 μs. A frequency range from 50 to 15,000 cycles per sec. was considered adequate.

The most important item in this apparatus is the flux controlling unit which is an amplifier operating in a negative feedback circuit. In the design of

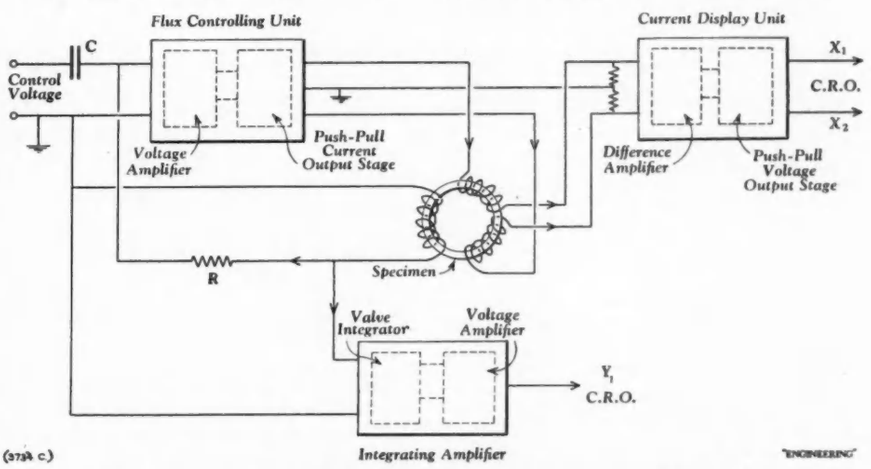

Fig. 3 Hysteresis loop tracer showing negative feedback from secondary winding.

* Paper read before Section G of the British Association at Sheffield on Thursday, August 30, 1956.

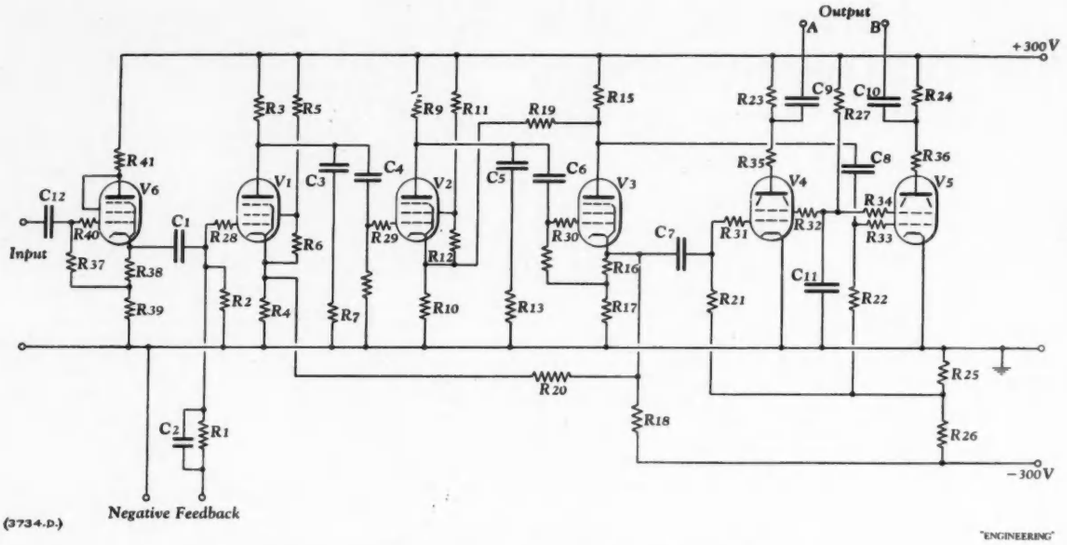

Fig. 4 Flux controlling unit.

amplifiers with feedback loops there are two essential requirements: (1) to attain a high gain when the feedback circuit is open, and (2) to prevent oscillations due to phase shifts when the feedback circuit is closed.

Negative feedback becomes positive when there is an overall phase change exceeding 90 deg. in the amplifier and feedback circuit. Oscillation will not occur, however, until the overall phase change is 180 deg. and the gain through the amplifier and the feedback circuit is also greater than unity, i.e., Nyquist's criterion is satisfied.[9] If there are only two sources of phase shift, then 180 deg. phase change will never be reached. But with three or more sources this amount of phase shift will be reached at some frequency, and the problem is then to reduce the gain of the amplifier at that frequency so that oscillations cannot build up.

It had been found that there was insufficient gain in a single valve amplifier, whereas two valves in cascade gave enough gain to drive a suitable output stage. To ensure equal peak magnetisation in both the positive and negative directions, a push-pull output stage was designed. A phase splitting stage was then necessary. Since each stage is a source of phase shift, these two stages together had to produce as little phase shift as possible at frequencies where the two other stages produced maximum phase shift (with a much reduced gain). Even with these precautions the change of phase caused by the specimen could produce oscillation at some particular frequency. Whether this was so could only be determined by constructing the apparatus and testing it.

FLUX CONTROLLING UNIT

In the case of a voltage amplifier having a gain of $-M$ which is connected, as shown in Fig. 2, to the impedances Z_1 and Z_2 which form a negative feedback circuit, the overall gain is given by:—

$$\frac{V_0}{V_i} = \frac{-M}{1+(M+1)\dfrac{Z_1}{Z_2}} \quad . \quad . \quad (1)$$

provided that V_i is obtained from a low impedance source.

In ordinary amplifier practice $M \gg 1$, but in this particular amplifier there are conditions when $M < 1$, so that provided

$$(M+1)\frac{Z_1}{Z_2} \gg 1 \quad . \quad . \quad (2)$$

then

$$\frac{V_0}{V_i} \simeq \frac{-Z_2}{Z_1} \quad . \quad . \quad . \quad (3)$$

Now, when

$$Z_2 = R, \text{ and } Z_1 = \frac{1}{j\omega C}$$

then

$$\frac{V_0}{V_i} = -j\omega RC \quad . \quad . \quad . \quad (4)$$

Thus the output voltage is the inverted differential of the input voltage, the minus sign indicating the phase reversal.

The general arrangement of the apparatus is shown in Fig. 3. The required input or control signal is fed in via the capacitor C at the input terminals of the current control unit. The induced e.m.f. in the secondary winding, as a result of the resistive feedback connection R, will be the inverted differential of the control voltage. The small error that actually occurs between the required e.m.f. and the induced e.m.f. provides the voltage to drive the amplifier. The output of this amplifier is a current, proportional to this error voltage, which magnetises the specimen in the required manner. Since the flux is the integral of the induced e.m.f., its waveform will be exactly that of the control voltage, if the error voltage is negligible.

For the purpose of calculating voltage gain, the two windings on the specimen have been included as part of the amplifier. It will thus be apparent that the value of M for this amplifier is directly proportional to the frequency. When equation (1) is re-written:—

$$\frac{V_0}{V_i} = -\frac{Z_2}{Z_1}\frac{1}{\dfrac{Z_2}{MZ_1}+1+\dfrac{1}{M}} \quad . \quad (5)$$

$\dfrac{Z_2}{MZ_1}$ is a constant for all operating frequencies and, being about $2{\cdot}5 \times 10^{-3}$, is sufficiently small to be neglected so that:

$$\frac{V_0}{V_i} = -\frac{Z_2}{Z_1}\frac{M}{M+1} \quad . \quad . \quad (6)$$

Therefore when M is large the output phase and amplitude are set directly by the ratio of the feedback and input impedances. When M is small the output differs from that set by the impedance ratio by the value of the term $\dfrac{M}{M+1}$. When Z_1 and Z_2 have the values assigned earlier, then:

$$\frac{V_0}{V_i} = -j\omega RC\frac{M}{M+1} \quad . \quad . \quad (7)$$

The value of M may be determined in the following way:

Let g be the conductance of the output stage,
„ A be the gain of the voltage amplifier,
„ N_1, N_2 be the primary and secondary turns,
„ f be the frequency $= \dfrac{\omega}{2\pi}$,
„ k be the ratio of change in flux to change in ampere-turns.

The ampere-turns applied to the specimen per volt r.m.s. input to the amplifier is given by gAN_1, and the induced e.m.f. per ampere-turn r.m.s. is given by $j\omega N_2 k$.

Thus the value of M is given by:—

$$M = j\omega gAN_1N_2k \quad . \quad . \quad (8)$$

In rectangular loop materials k will have two widely different values, according to whether the material is magnetically saturated or unsaturated.

The overall sensitivity, allowing for the non-linearity of the material, may be obtained in the following manner :—

First, assuming a linear B-H relationship, with an induced e.m.f. of $-N_2\dfrac{d\Phi}{dt}$ there will be a corresponding voltage of $N_2\dfrac{d\Phi}{dt}\dfrac{1}{M}$, the error voltage, at the junction of R and C in Fig. 3. The current through R will be $\dfrac{N_2}{R}\dfrac{d\Phi}{dt}\left(1+\dfrac{1}{M}\right)$. The voltage across C due to this current will be $\dfrac{N_2}{RC}\Phi\left(1+\dfrac{1}{M}\right)$. The input voltage V_i will be the sum of the capacitor voltage and the error voltage, that is,

$$V_i = \frac{N_2}{M}\frac{d\Phi}{dt} + \frac{N_2}{RC}\Phi\left(1+\frac{1}{M}\right)$$

This is then modified by making allowance for the initial magnetising current, denoted I_0, necessary to bring the core to the steep part of its loop. The voltage at the junction of R and C will be $\dfrac{I_0}{gA}$ before there is any induced e.m.f. The current in R is $\dfrac{I_0}{gAR}$ and the input voltage corresponding to this is:

$$\frac{I_0}{gA} + \int\frac{I_0\,dt}{gARC}.$$

The resultant input voltage V_i, the sum of the two previous results is then:

$$\frac{I_0}{gA} + \frac{1}{gARC}\int I_0\,dt + \frac{N_2}{M}\frac{d\Phi}{dt} + \frac{N_2\left(1+\dfrac{1}{M}\right)}{RC}\Phi \quad . \quad . \quad . \quad (9)$$

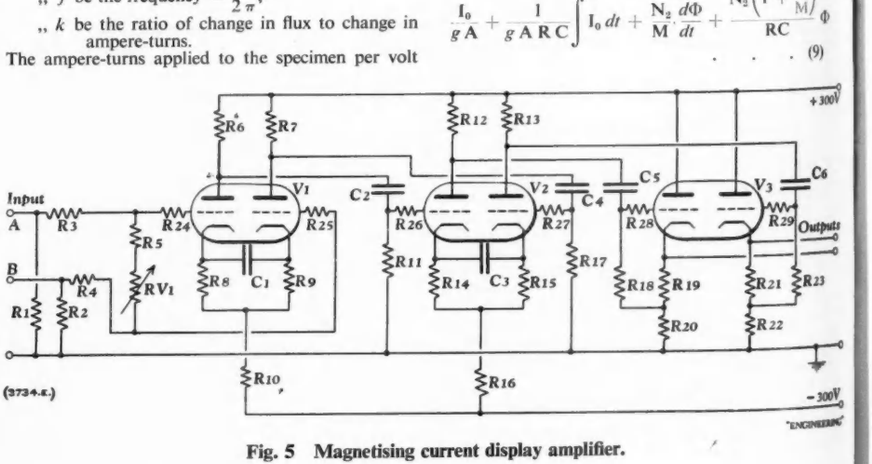

Fig. 5 Magnetising current display amplifier.

Of these $\frac{I_0}{gA}$ and $\frac{N_2}{M}\frac{d\Phi}{dt}$ can be neglected, so that the control unit will require an extra input, to allow for the width of the hysteresis loop, of value $\frac{1}{gARC}\int I_0\,dt$. This extra term applies for each period of flux reversal and becomes negligible at frequencies of loop tracing above 500 cycles per sec. in the system being described.

The circuit diagram of the current control unit is given in Fig. 4. The valve V_3 is a cathode follower used to provide a low source-impedance to the input of valve V_1. This stage may be removed if a voltage source of low output-impedance is used.

The valves V_1 and V_2 form a two-valve cascaded amplifier which drives valve V_3 as a phase splitter with equal anode and cathode loads. The valves V_4 and V_5 are driven in Class "B" push-pull by the two outputs from valve V_3. The output currents from the push-pull stage pass through capacity couplings to the two magnetising windings on the specimen. Voltage negative feedback from the secondary winding on the specimen is applied to the grid of valve V_1 through the resistance R_1. The capacity coupling C_1 at the grid of valve V_1 is the input impedance.

In order to prevent high-frequency oscillations, the stage gains of valves V_1 and V_2 are greatly reduced at the higher frequencies. For V_1 this is accomplished by the capacitor C_2 and resistor R_7 which are in parallel with the anode load resistor R_3. The value of R_7 is much less than that of R_3, so that when the reactance of C_2 is low, the effective anode load is then R_7. The capacitor C_5 and resistor R_{12} act similarly on R_9 to reduce the gain of V_2. This has a disadvantage of producing a considerable amount of phase shift at the frequencies when these shunting devices behave as almost pure reactances. This is overcome by the use of a small degree of negative feedback from the connection of resistors R_4 and R_{20}. Without any one of these measures the system oscillates at frequency well above 250 kilocycles per sec.

Maximum output current from valves V_4 and V_5, type 807 (CV124), is obtained with a signal at the grid of V_1 having a peak value of 16 mV. The peak output current is then equivalent to 200 mA through a single winding.

Substituting the numerical values into equation (8) :—

$$gA = 12\frac{A}{V};\ N_1 = 50;\ N_2 = 150;$$

$$k = \frac{4 \times 10^{-7}}{9 \cdot 1}\ \text{W b per A T}$$

gives a value of $M = 2 \cdot 5 \times 10^{-2} f$, and so $M = 1$ when $f = 40$ cycles per sec.

This, however, is the mean value of M when the peak ampere-turns are 9·1, for which the relative permeability μ_r is 450. The value of μ_r in the saturated material is, however, about 20. For flux changes in the saturated condition only, $M = 1$ at a frequency of 900 cycles per sec.

Insertion of numerical values into equation (9) gives

$$V_i = 0 \cdot 0036 + 360\int dt + \frac{150}{M}\frac{d\Phi}{dt} + 15 \times 10^6\left(1 + \frac{1}{M}\right)\Phi$$

where: $\int dt \gg 10^{-2}$ (its value at 50 cycles per sec.), $\frac{d\Phi}{dt} \gg 0 \cdot 4$ (the value for 2 μs flux reversal). Now at maximum amplitude $\Phi = 4 \times 10^{-7}$ and $\frac{150}{M}\frac{d\Phi}{dt} = \frac{V_0}{M} \gg 0 \cdot 05$, i.e.

$$V_i = 6\left(1 + \frac{1}{M}\right) + 360\int dt \quad . \quad (10)$$

where normally $M > 1$ for all operating frequencies.

It has been found in practice that for operation above 8 kilocycles per sec. instability and consequent self-oscillation will occur if the amplifier becomes overloaded and one of the valves draws grid current. This stops when the control voltage is reduced sufficiently. The very low value of capacity C_2 improves the high-frequency stability, but introduces a tendency towards low-frequency oscillations at a few cycles per second. For these reasons it was found useful to be able to readjust C_2 occasionally to suit a particular frequency of operation.

The upper limit of frequency at which the amplifier ceases to exercise a tight control over the flux has not been measured. When the control voltage had a rise time of 3 μs the flux wave was only lengthened by about 0·5 μs although a phase shift of 1 μs appeared between the current and induced e.m.f. waves, with the e.m.f. iagging. Operation at 1 kilocycle per sec. with a superimposed voltage of frequency about 100 kilocycles per sec. was successful although it was impossible to check whether the control and flux waveforms were identical.

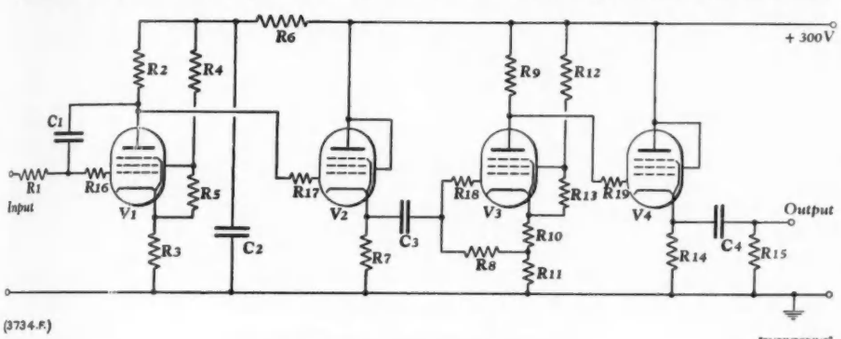

Fig. 6 Integrating amplifier.

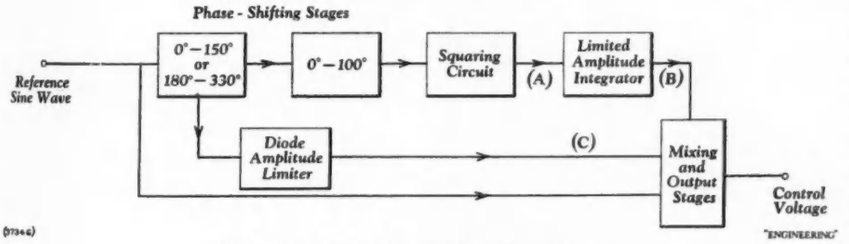

Fig. 7 Control voltage waveform generator.

MAGNETISING CURRENT DISPLAY AMPLIFIER

The voltage input is derived from the two monitoring resistors (R_1 and R_2 in Fig. 5) each in series with one of the magnetising windings. When these two resistors are in the same ratio as the turns on their respective windings, the voltage difference between their two ends is proportional to the value of ampere-turns applied to the specimen. Thus the value of H is proportional to this voltage difference.

The first stage in this unit is a twin-triode voltage-difference amplifier using the "long-tailed pair" circuit. The conventional circuit is modified by the inclusion of individual resistors (R_8, R_9) in series with the two cathodes to provide current negative feedback. This enables a large input voltage to be amplified with negligible departure from linearity, but unbalances the two outputs from the anodes. This modification has the important advantage of making it possible to compensate at the cathode (with C_1) for stray capacities between the anode circuits.

The second stage is a similar difference amplifier which then gives two outputs balanced with negligible error, and provides an output large enough for direct connection to the X-plates of an oscilloscope.

Since a low output-impedance is essential, firstly to reduce any electrostatic pick-up to negligible proportions, and secondly to reduce the effect of the high capacity of the output leads to earth and to each other, the amplifier has been followed by a cathode-follower output stage.

A peak output of 50 volts from each output terminal may be obtained without distortion in the amplifier. The corresponding input voltage between the two grids of valve V_1 is then 3 volts peak. The provision of gain control had to be made outside the amplifier to preserve a constant value of phase shift at all gain settings. The phase shift at the high frequencies is adjusted to a minimum by the correct choice of values for capacitors C_1 and C_2. In the unit constructed, the phase error is equivalent, at 15 kilocycles per sec., to a lag of 2 μs. The present design could be much improved in this respect if the amplifying triodes were replaced with pentodes, but at the time of construction a high-frequency response extending beyond 100 kilocycles per sec. was not envisaged.

INTEGRATING AMPLIFIER

This uses negative feedback over a single valve stage. Referring to Fig. 2, when $Z_1 = R$, $Z_2 = \frac{1}{j\omega C}$ and $M \gg 1$, then from equation (3) $\frac{V_0}{V_i} = -\frac{1}{j\omega RC}$ and the valve stage gives an output

$$V_0 = -\frac{1}{RC}\int V_i\,dt \quad . \quad . \quad (11)$$

This result is only strictly valid when the input is sinusoidal and the time of one cycle is much less than the time-constant RC, which is the case for all R-C integrating arrangements unless positive feedback is used to correct, in the valve amplifier, the error caused by the finite grid voltage needed to give the output. Further discussion on the errors in this and other integrating circuits is given in one of the appendices.

The high-frequency response of the circuit is maintained by using a cathode-follower stage after the integrating stage, as in Fig. 6. A further amplifier and a cathode-follower output stage then follow. The low-frequency response is maintained by dispensing with capacity coupling between stages, where possible.

At a frequency of 50 cycles per sec., the integrator stage has a phase error of 2 per cent. and the two C-R couplings, after the cathode-follower stages, introduce a further 1 per cent. phase error. At higher frequencies the phase error is inversely proportional to the frequency.

It is impracticable with the present design to obtain a much better low-frequency response. The output from the integrator is inversely proportional to the product RC, as given in equation (11), and its effective time-constant is the value of RC multiplied by the valve amplification. This latter is already at a practical maximum. Only an increase in the value of RC will give an extended low-frequency range to the integrator. The present value of gain and low-frequency response in the succeeding stages is such that low-frequency noise in valve V_1 is at a level which is just tolerable, there being occasional objectionable jumps in the trace shown on the oscilloscope. A further increase in the gain and low-frequency response, which would be needed if RC were increased, would cause these sudden movements of the trace to make viewing of the screen most irritating. Any method of obtaining a better low-frequency response would entail considerable re-design of this unit.

CONTROL VOLTAGE WAVEFORM GENERATOR

In alternating current testing of magnetic materials, a sinusoidal induced e.m.f. normally occurs (since the magnetising winding is more often than not connected to a source of sinusoidal voltage) and is used as a basis for comparisons between different materials. The corresponding flux waveform will also be sinusoidal. Thus, the basic hysteresis loop is the one for which flux changes are sinusoidal, and departures from this will in effect give rise to non-standard loops. To study the material under more typical conditions where pulse waveforms are met, periodic non-sinusoidal waveforms must be generated.

A reference sine wave is supplied to this unit from

a beat-frequency oscillator. The functional diagram of the waveform generator is given in Fig. 7. and waveforms relating to different sections of the unit are given in Fig. 8.

The first two stages are each simple triode phase-shifters as described by Raistrick.[10] The output from the second stage is a sine wave, the phase of which can be varied through the complete range of 360 deg., and is applied to a Schmidt trigger circuit which produces the square wave shown in Fig. 8 (*a*). The bias on the first grid of this circuit can be varied so that the point in the cycle at which the triggering action takes place can be shifted through nearly 180 deg., giving an on-off ratio variable over an extremely wide range. Both edges of this square wave can therefore be obtained at almost any point throughout the reference sine wave.

This square wave is applied through a high resistance to the grid of the next valve. Due to the effect of grid-to-earth capacity the output from this valve is approximately the integral of the square wave. The amplitude of this wave is limited by grid current

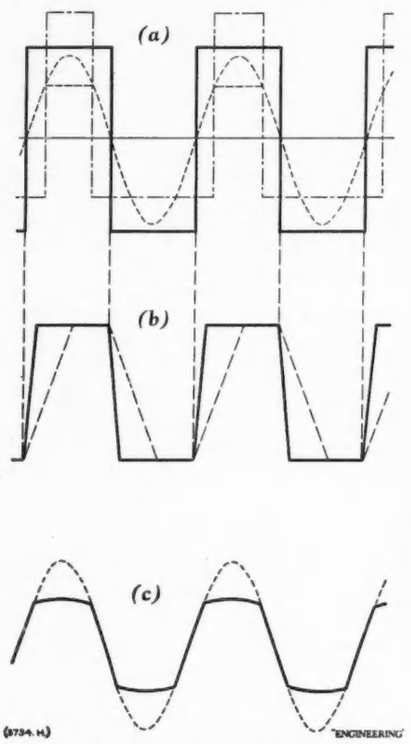

Fig. 8 Waveforms at (A), (B), (C) in Fig. 7.

in one direction and a diode in the other direction, so that the waveform becomes trapezoidal instead of triangular. (Fig. 8(*b*).) The amplitude of the square wave applied to this circuit is variable and so the slope of the sides of this trapezoidal wave can be varied over a wide range. The time of rise can be made as short as 2 μs or longer than 1 ms., but in the latter case further capacity has to be added in parallel to the grid-to-earth capacity.

A sine wave having its phase the reverse of the reference is applied through an input resistance to a diode limiting-circuit. One diode will conduct when the instantaneous voltage is greater than a pre-set value and the other will conduct when the instantaneous voltage is less than a second pre-set value. When either diode conducts, it shunts a low value resistance across the output of this circuit, thus greatly reducing the output amplitude of the sine wave. When neither diode conducts, the output amplitude remains unchanged and is then equal to the input amplitude. The waveform is shown in Fig. 8 (*c*).

This waveform, the reference sine wave and the trapezoidal wave, each with independent control of amplitude, are then added in a mixing circuit. This is then followed by a low output-impedance stage which supplies the required control voltage for the loop tracing system.

It must be noted that the various waveforms which may be generated, with their sudden or gradual variations in rate of change, cannot represent all the possible conditions under which the cores may operate. However, these waveforms can be made to simulate very closely the most likely practical waveforms.

A further use of controlled flux changes is the prediction, with measurements taken from the oscillographic record, of the likely behaviour of the core material. It would appear that the behaviour of the material under particular conditions of flux change can be readily estimated if details of the previous flux cycle are known. Preliminary observations indicate that the extent to which the material has been saturated in any cycle has a marked effect on its behaviour in the cycle which follows. This particular aspect of the uses of this system will form the subject matter of a later publication.

CONCLUSIONS

The main advantage of this system, apart from its comparative economy, lies in its ability to trace a hysteresis loop under almost any desired conditions of rate of flux change. The rate of change may be varied, over any part of the cycle, through a continuous range of 5,000 : 1. This can be carried out with any amplitude of flux up to the given saturation value, and for any frequency in the range 100 to 15,000 cycles per sec. Both sinusoidal flux and sinusoidal m.m.f. may be obtained, the latter without the feedback from the secondary winding.

Materials other than ferrites, whether rectangular looped or not, may be tested when wound with suitable numbers of turns. Cores having larger values of enclosed flux may be tested at frequencies lower than 100 cycles per sec., since the overall gain without feedback can be increased, and the accuracy of flux control still maintained.

There appear to be three limitations to this system. The first is the necessity for a large number of turns on each winding on the specimens. It was thought better not to use current or voltage transformers because of the errors involved. These numbers of turns used are also those used in the counting system in which the cores would operate. The second is the instability with overload. This, presumably, can be overcome by some modifications of the circuit that enable the stages concerned to handle larger signals, and also give an improved high-frequency response (i.e., reduction in phase-shift). Finally there is the low-frequency limit to the accuracy of the system. An improvement in the integrator and an increase in inter-valve coupling time-constants may lead to fairly accurate tracing down to 10 cycles per sec., or less, but as far as ferrite materials are concerned, the hysteresis loop at 100 cycles per sec. is hardly different from the static loop, given sinusoidal flux changes.

The apparatus described has been built to deal with one particular problem. Its possible uses in other applications have not been discussed. However, this system, with appropriate modifications, can be used to trace out dynamic characteristics of components or apparatus which, due to non-linearity, would distort the test waveform if this were not controlled by the feedback.

ACKNOWLEDGMENTS

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APPENDIX I

Power Supplies

The apparatus described in this paper will function correctly when the positive and negative supplies at 300 volts are stabilised. The low output-impedance of these supplies prevents any unwanted coupling between the various stages in the equipment, which could occur through the high-tension leads. Self-oscillation would occur at several frequencies if this method of decoupling were not adopted.

The positive supply is stabilised by an electronic series-stabiliser which has an output impedance of about one ohm, and can deliver currents in excess of 250 mA. The output voltage may be set in the range 250 to 350 volts. Random changes in the output voltage are negligible, and the drift during the warming-up period amounts to about 1 per cent. in several hours.

A neon-tube regulator is used for the negative supply. The amount of ripple voltage present, although considerable (0·5 volt), has no adverse effect on the apparatus. The small fluctuations which occur in this supply also have no effect.

The heater supplies are unstabilised, but provided that the valve heaters are operated within their specified range, the equipment will function correctly. Electrostatic pick-up from the heater leads is minimised by earthing an artificial centre-tap on the supply.

APPENDIX II

R-C Integrating Circuits

The electrical integration of a voltage may be performed, with a limited degree of accuracy, by a combination of resistive and reactive elements. The resistance-capacitance circuit, in various forms, is generally used. A brief analysis of the most common arrangements has been carried out in order to show their limits of accuracy.

Simple R-C Integrator.—This circuit, given in Fig. 9, is most commonly used. It is normally supplemented by a high-gain amplifier connected to the output terminal.

Where V_i is the input voltage, and V_0 the output voltage:—

$$\frac{V_0}{V_i} = \frac{1}{RC}\int (V_i - V_0)\,dt \qquad (12)$$

(i) With a sinusoidal input:—

$$\frac{V_0}{V_i} = \frac{1}{j\omega CR}\,\frac{1}{1+\frac{1}{j\omega CR}} \quad . \quad (13)$$

and provided that $\omega CR \gg 1$, then

$$\frac{V_0}{V_i} \sim \frac{1}{j\omega CR} \quad . \quad . \quad (14)$$

The output from this circuit is then the integral of the input, but there is a phase error (ϕ) which is given by

$$\tan\phi = \frac{1}{\omega CR} \quad . \quad . \quad (15)$$

and the error in the amplitude of the output is given by

$$\frac{-1}{2(\omega CR)^2} \quad . \quad . \quad . \quad (16)$$

(ii) The transient response is:—

$$V_0 = V_i\left(1 - e^{-\frac{t}{CR}}\right) \quad . \quad . \quad (17)$$

Feedback Time-Constant or Miller Integrator.—This is based on the arrangement shown in Fig. 2, whereby the time-constant is multiplied by the value of the gain of the amplifier. The amplifier may be either a single valve (normally a pentode) or a multi-valve unit.

The general case of an amplifier with an output impedance, as shown in Fig. 10, will be considered first.

Let r_a be the output or anode slope resistance,
,, g_m be the mutual conductance,
,, μ be the amplification factor,
,, a be the ratio $\frac{r_a}{R_L}$
,, b be the ratio $\frac{r_b}{R}$
,, $-M$ be the gain of the amplifier: $M = \frac{\mu R_L}{R_L + r_a}$

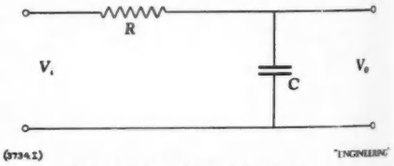

Fig. 9 Simple R-C integrator.

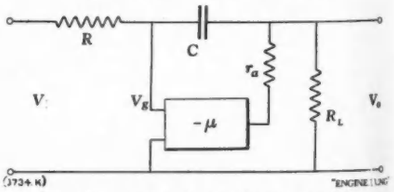

Fig. 10 Feedback or Miller integrator.

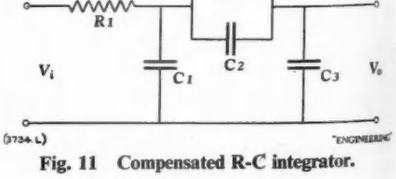

Fig. 11 Compensated R-C integrator.

or $M = g_m R_L$, depending on the value of a.

These terms apply equally well to the single or multi-valve amplifier. Equating currents in the circuit of Fig. 10:—

$$\frac{1}{R}(V_i - V_g) = C(\dot{V}_g - \dot{V}_0) = \frac{1}{r_a}(V_0 + \mu V_g) + \frac{V_0}{R_L}$$

This, after eliminating V_g and $\dot{V}_g$, simplifies to the differential equation:—

$$V_0\left(1 + \frac{a+b}{\mu+1}\right) = \frac{-\mu}{(\mu+1)CR}\int\left(V_i + \frac{V_0}{M}\right)dt + V_i\frac{b}{\mu+1}, \quad (18)$$

and when $\mu \gg 1$, $a > 1$, then

$$V_0 = \frac{-\mu}{(\mu+1)RC}\int\left(V_i + \frac{V_0}{M}\right)dt + \frac{V_i}{g_m R}. \quad (19)$$

(i) With a sinusoidal input:

$$\frac{V_0}{V_i} = \frac{-\mu}{j\omega CR(\mu+1+a+b)} \cdot \frac{1 - \frac{j\omega CRb}{\mu}}{1 + \frac{1+a}{j\omega CR(\mu+1+a+b)}}, \quad (20)$$

and provided that $M\omega CR \gg 1$, then

$$\frac{V_0}{V_i} \simeq \frac{M}{M+1}\cdot\frac{-1}{j\omega CR} \quad (21)$$

The phase error is given by:—

$$\tan\phi = \frac{1+a}{\omega RC(\mu+1+a+b)} - \frac{\omega C}{g_m} \quad (22)$$

which is zero when $(\omega RC)^2 \simeq \frac{g_m R}{M+1}$.

In the expression for phase error, the term $\frac{\omega C}{g_m}$ can be exactly cancelled out for all frequencies by the inclusion of a resistance of value $\frac{1}{g_m}$ in series with the feedback capacitor C, whereupon the phase error is given by $\tan\phi \simeq \frac{1}{(M+1)\omega RC}$

(ii) Transient response:

$$V_0 \simeq -V_i\left(M + \frac{1}{g_m R}\right)\left(1 - e^{\frac{t}{(M+1)RC}}\right) + \frac{V_i}{g_m R}. \quad (23)$$

The special case will be considered when $r_a = 0$, and $M = gm\,R$. These conditions apply to an amplifier with a cathode-follower output stage. The general solution is now:

$$V_0 = \frac{-M}{(M+1)RC}\int\left(V_i + \frac{V_0}{M}\right)dt. \quad (24)$$

Sinusoidal response

$$\frac{V_0}{V_i} = \frac{M}{M+1}\cdot\frac{-1}{j\omega RC}\cdot\frac{1}{1 + \frac{1}{j\omega RC(M+1)}}, \quad (25)$$

giving

$$\tan\phi = \frac{1}{\omega RC(M+1)}. \quad (26)$$

Transient response:—

$$V_0 = -MV_i\left(1 - e^{-\frac{t}{(M+1)RC}}\right). \quad (27)$$

A feedback integrator has the advantage over a simple R-C integrator with amplifier, of operating in such a way that the effects of valve non-linearity and undesirable voltage pick-up are greatly reduced. When both types of integrator have amplifiers of equal gain, they are then alike in all other respects.

Compensated R-C Integrator.—In this circuit, shown in Fig. 11, the slight leading phase error in the simple integrator $\left(\text{time-constant} = \left(C_1 + \frac{C_2C_3}{C_2+C_3}\right)R_1\right)$ is corrected by the circuit of R_2, C_2 and C_3 which introduces a phase lag that is inversely proportional to frequency. It would appear that Wiegand and Hansen[6] first used this form of compensation, which was also used by Scherb.[7]

Equating currents in the circuit of Fig. 11:—

$$\frac{V_i - V_2}{R_1} - C_1\dot{V}_2 = \frac{V_2 - V_0}{R_2} + C_2(\dot{V}_2 - \dot{V}_0) = C_3\dot{V}_0.$$

After eliminating V_2 and $\dot{V}_2$ this gives rise to the differential equation:

$$\dot{V}_0 R_1 R_2 C_2^2(m + n + mn) + V_0 C_2[R_1(m+n) + R_2(1+n)] = \int(V_i - V_0)\,dt + R_2 C_2 V_i \quad (28)$$

where $m = \frac{C_1}{C_2}$, and $n = \frac{C_3}{C_2}$.

With a sinusoidal input, replacing

$(\omega C_2)^2 R_1 R_2 (m + n + mn)$ by A,

$\omega C_2[R_1(m+n) + R_2(1+n)]$ by B, and

$\omega C_2 R_1(m + n + mn)$ by ωT,

then

$$\frac{V_0}{V_i} = \frac{\omega C_2 R_2}{j(A-1)}\cdot\frac{1 + \frac{1}{j\omega C_2 R_2}}{1 + \frac{B}{j(A-1)}}. \quad (29)$$

and provided $A \gg 1$,

$$\frac{V_0}{V_i} \simeq \frac{1}{j\omega T}. \quad (30)$$

The phase error is given by:—

$$\tan\phi = \frac{1 - (\omega C_2)^2 R_2[R_1 - mn\,R_2(1+)n]}{\omega C_2 R_2(A-1)} \quad (31)$$

and $\phi = 0$ when either (*a*) $\omega = \infty$,

or (*b*) $(\omega C_2)^2 R_2[R_1 mn - R_2(1+n)] = 1$.

Let ω_0 denote the value of ω satisfying solution (*b*), i.e.,

$$\frac{1}{\omega_0 C_2 R_2)^2} = \frac{R_1}{R_2}mn - (1+n). \quad (32)$$

At frequencies above $f_0 = \frac{\omega_0}{2\pi}$ the phase error becomes lagging, and this reaches a maximum at $f \simeq \sqrt{3}\,f_0$ when

$$\tan\phi \simeq \frac{2}{3\sqrt{3}}\cdot\frac{1}{(\omega_0 C_2 R_2)^2\,\omega T}. \quad (33)$$

A comparison of the simple and the compensated integrators shows the following:

Let the phase error of the simple circuit at a frequency f_0 be of the same magnitude as that of the compensated circuit at a frequency $\sqrt{3}\,f_0$, so that the two integrators have comparable phase errors for all frequencies above f_0. Then the output amplitude of the compensated circuit will be $\frac{3\sqrt{3}}{2}(\omega_0 C_2 R_2)^2$ times that of the simple integrator.

At frequencies below f_0 the phase error in the compensated arrangement increases very rapidly and exceeds that of the simple circuit: at a frequency $f \simeq 0{\cdot}6\,f_0$ the phase errors of the two are equal.

This compensated arrangement can also be used with the capacitor C_2 augmented by feedback from a valve amplifier, and the preceding notes on this type of integrator will also apply here.

REFERENCES

[1] Zerbini, V. "Hysteresigraphs": *L'Elettrotecnica*, vol. 32, page 182, 1945, and A.C.S.I.L. Translation No. 435.

[2] Cioffi, P. P. "A Recording Fluxmeter of High Accuracy and Sensitity": *Rev. Sci. Instr.*, vol. 21, page 624, 1950.

[3] Ross, H. McG. "An Automatic Plotter for Magnetic Hysteresis Loops": *Proc. I.E.E.*, Paper No. 1637, vol. 101, Pt. II, page 417, 1954.

[4] Brockman, F. G., and Steneck, W. G. "Electronic Integrating Fluxmeter": *Phillps Technical Review*, vol. 16, page 79, 1954.

[5] Ledward, T. A. "Magnetic Hysteresis Loops": *Electrician*, vol. 117, page 217, 1936.

[6] Wiegand, D. E., and Hansen, W. W. "A 60 c/s Hysteresis Loop Tracer for Small Samples of Low-Permeability Material": *Trans. A.I.E.E.*, vol. 66, page 119, 1947.

[7] Scherb M. V. "Cathode-Ray Magnetisation Curve Tracers": *Rev. Sci. Instr.*, vol. 19, page 411, 1948.

[8] Kittl, E. "An Accurate Electronic Tracer for Dynamic Characteristics of Magnetic Materials": *Trans. A.I.E.E.*, vol. 74, Pt. 1, page 407, 1955.

[9] Nyquist, H. "Regeneration Theory": *Bell S.T.J.*, vol. 11, page 126, 1932.

[10] Raistrick, W. G. "Phase-Shift Oscillators": *Wireless World*, vol. 56, page 409, 1950.

[11] Greig, J., and Shurmer, H. V. "Iron Losses under Superimposed Alternating Inductions": *P.O. Symposium—Soft Magnetic Materials for Telecommunications*, page 27. (Pergamon Press—1953.)

[12] Jackson, G. R., Melville, W. S., and Sewell, D. W. R. "Some Problems of Oscillographic Measurement of Characteristics of 'Rectangular'-Loop Magnetic Materials": *ibid.*, p. 191.

THE ECONOMIC EFFECTS OF AUTOMATION*

By Professor H. D. Dickinson, M.A.

Automation may be defined as mechanisation plus automatic control. Thus, in a machine shop, automatic machinery may be already in use, but each job needs to be moved from one machine to another and put into position; the machine, even though fully automatic, needs to be started by an operator (even if it stops itself automatically), and various other operations require deliberate human control. In a fully automatic factory all these processes can be carried out by automatic control, which is thus a sort of super-mechanisation. Another example can be taken from chemical engineering, where long and complicated reactions are already automatised, the human agent being reduced to watching pointers on a control panel and making the necessary adjustments of flow-rates, temperatures, pressures, etc. The works become fully automated if these functions are taken over by automatic controls, whereby the pointers of the various meters and gauges themselves actuate the appropriate adjustments. It is not only in industrial processes that automatic control can be applied. Clerical work can now be done by electronic computers, making it possible for clerical staffs to be drastically reduced.

Automation is seen therefore to be something that is not totally new: it is simply a further development of a tendency that has long been with us. The economic problems of automation are essentially the same as those created in the past by the introduction of mechanised processes into industry, notably the displacement of labour by labour-saving machinery. However, it may well be that the magnitude of the problems likely to arise in the near future may be so great as to make the precedents of the past very fallible guides.

Little in the way of hard statistics is available; but individual cases of automation are on record where the direct displacement of labour is of the order of 75 or 80 per cent. (The net displacement of labour is always less than this because of the amount of indirect labour required to produce and service the automatic plant. Even so, the net displacement may be of a magnitude that recalls the early industrial age in Britain.)

As always with the introduction of improved mechanical processes, the saving of labour is not the only important aspect of the new techniques. One important result always is that, not only can old jobs be done with fewer workers, but new jobs can be undertaken that could never have been done at all with the old methods. A good example of this is the use of electronic computers, which not only greatly shorten the time taken to do ordinary calculations, but can perform calculations that would previously have required a quite impossible number of man-hours.

LONG-PERIOD CONSEQUENCES

As in the case of ordinary mechanisation, the long-period results of automation may be expected to be almost wholly for the benefit of mankind. It will, in the long run, enable the joint efforts of human beings to produce more material goods with a less expenditure of time and effort than before, thus making possible a far higher degree of satisfaction of wants for all mankind. Of course, certain very long-range considerations obtrude themselves here: problems arising out of the use of leisure, the sufficiency of supplies of natural raw materials, the very long-run consequences of population growth. These problems, I am confident, can be solved by a robust application of scientific technique and of a rational attitude towards problems of human ecology. It is to the problems of the medium-long period that I wish to direct attention.

These problems are of two kinds (inter-locked.

* Paper read before Section G of the British Association at Sheffield on Monday, September 3.

like all social problems), problems of labour transference and problems of income distribution. The first group of problems arises from the fact that any massive reduction in the labour-time taken to make a particular product nearly always makes redundant some of the labour at present employed in that branch of production, and consequently, if full advantage is to be taken of the saving of labour, this redundant labour must be applied to the production of other things that satisfy some human needs previously unsatisfied. To leave it permanently unemployed or even to continue to employ it unnecessarily in its old job by some form of " making work " is simply to frustrate the original labour-saving innovation. This means that we must look carefully at our social arrangements that are concerned with the flow of labour between one job and another.

The second group of problems arises out of the fact that big changes in the relative demand for labour and for capital, or in the relative demand for one kind of labour as compared with another kind of labour, tend to give rise to changes in the distribution of the social product as between labour and capital or as between workers doing one kind of job and workers doing another kind of job. If the average social product per head is increasing fast enough it may be that everyone is so satisfied with the larger lump of cake that he has received that he will not bother to make comparisons of the relative sizes of his lump and of other people's lump. But, unless the average social product grows very rapidly indeed, it is probable that the absolute size of some people's lump of cake will shrink. Even if this does not happen, the tendency to look at relative shares and compare them in the light of some concept of social justice is so strong nowadays that I doubt whether even a rapid rate of general material progress will save us from serious social unrest and social conflict.

TRANSFERENCE OF LABOUR

(1) In the preliminary remarks I have said that labour-saving innovations nearly always make labour redundant in the employments where they are introduced. I said " nearly always " because in special cases the demand for the goods in whose production labour is saved may increase by such an amount as will counteract the reduction in the quantity of labour required to produce each unit of the goods. For example, if the net saving of labour is 75 per cent. and if the quantity of goods sold increases fivefold, the demand for labour will increase by 25 per cent.; in this case, far from there being redundancy, the industry will attract labour from other employments. This may happen—it has happened—but it cannot be relied upon to happen, and in most cases it will not happen.

The conditions that are most favourable to such an expansion in demand are two:

(*a*) A general high rate of increase of the national income, of which the most likely cause is a rapid introduction of technological improvements in other branches of production.

(*b*) The willingness of producers in branches of production where technological progress is taking place to reduce the prices of their goods in proportion to the reduction of cost. Reduction of price tends to stimulate an increase in the demand for the particular good (independently of any expansion in the economy as a whole).

Even if this reduction of price corresponding to falling cost takes place, it by no means follows that the resultant expansion in demand will re-absorb surplus labour in the automated industry. It may or it may not. How much the expansion of demand will counteract the initial reduction in the amount of labour required to produce each unit of output depends upon two factors: (i) the original proportion of wages to total cost; and (ii) the elasticity of demand for the product. If the original proportion of wages cost is high and if the demand for the product is highly elastic, the increase in the number of units of the particular commodity sold may more than counterbalance the reduction in the amount of labour used per unit. In this case, the effect of labour-saving innovation will actually be to increase the demand for labour in the industry in which innovation is introduced. The technical triumphs of mechanisation in British industry that were achieved during the Nineteenth Century, and those that are being achieved in the United States at the present time, are due very largely to the existence of a competitive régime, in which entrepreneurs are forced to reduce their prices (at least after a brief delay) parallel with falling costs. In this way the benefits of mechanisation are spread as widely as possible throughout the entire economy, and promote an expansion of demand that absorbs the whole of the potential product of industry.

Unfortunately, the general trend of present-day economic organisation in Britain is away from this. Price reduction is considered almost indecent. Even those business-men who speak most loudly in favour of competition are apt to lower their voice when it comes to price cutting. Trade associations whose purposes include the fixing of prices and the restriction of output are widely prevalent through British industry although it is possible that the Restrictive Practices Act will curb activities in this direction. Organised labour, faced with the possibility of improved technique, has, as its first thought, the desire to stop its introduction, and, if this proves impossible, its second thought is to appropriate as large a proportion as possible of the benefit in the form of higher wages or shorter hours (or both) for the particular group of workers concerned. Neither organised capital nor organised labour seems ever to give a thought to the interests of consumers in general or to the efficient functioning of the economy as a whole.

(2) But apart from the special case of an automated industry actually expanding its labour force, we must consider the general case of labour-saving innovations. In general, we cannot look for such an expansion of demand for the product of the particular industry as will entirely offset the reduction in labour cost per unit of product. In most cases automation will result in the displacement of labour.

This general case is not, in the long run, a cause for disquiet. The labour that is redundant to one industry can be absorbed into employment by expansion in the output of all the other industries. General full employment can be achieved, even in the presence of a persistent tendency to redundancy in particular industries. Since the days of Keynes and Roosevelt we know, in broad outline, how to do it. The measures required would be very largely (*a*) low interest rates (short-term), maintained by a vigorous monetary policy, (*b*) public works, (*c*) social services, and (*d*) redistributionary taxation designed to counteract any shift from wages to profits in the general distribution of income. It should be pointed out that, even with such measures, the more prices fall with reduced costs of production, the greater is the spontaneous tendency towards expansion in the demand for labour in the economy as a whole, and the less will be the need for vigorous measures *à la* New Deal. On the other hand, the stronger the tendencies towards the monopolisation, by either capital or labour, of the benefits of technological improvement, the more vigorous would be the counter-deflationary measures required, and the greater the social and political strains set up in a predominantly private enterprise economy (*cf.* the New Deal in the U.S.A.).

(3) Assuming that by appropriate measures we succeed in maintaining at a high level the aggregate demand for labour in the economy as a whole, what is the general picture likely to be? The sort of massive reductions in the amount of labour per unit of product that automation is expected to bring about makes it likely that any compensatory expansion in the demand for labour must be looked for in other industries and occupations. In other words, the introduction of automation will raise in a peculiarly acute form the problems of industrial transference and the need for a high degree of mobility of labour, both as between places and as between occupations. (Even if full compensation does take place in the automated industries and the demand for labour in them is not reduced, there will still be very big problems of retraining, redeployment and regrading since, even if the same labour is employed as before, it will not be employed in the same way or on the same processes as before.)

APPRENTICESHIP AND DEMARCATION

This means that, if the full advantage of automation, in the form of a general increase in production and a rise in the real national income, is to be realised, it will be necessary to have a high degree of fluidity of labour, involving a willingness of workers to change jobs and work places and to accept the necessity of retraining for new jobs. It is obvious that emphasis on apprenticeship rules, on traditional craft demarcations, and on traditional rules regarding staffing of machines is entirely incompatible with such a state of affairs.

We have seen that the best chance of avoiding unemployment lies in the expansion of demand f r commodities other than those affected by automation. What sort of commodities will in fact be demanded? The countervailing expansion in employment must be in occupations less suitable for automation; not necessarily in manufacturing industry, but also in transport, distribution, entertainment, and services. What are these occupations? They comprise most of those industries producing goods for highly individualistic consumers: most luxury trades come into this category, as do those producing for specialised groups of amateurs, such as fishermen, golfers, makers of model machinery, etc. Research, experimental work and most forms of repair and maintenance work come into this category. Unfortunately, with the tendency to mass markets, which automation will foster, and with the now widespread tendency to scrap early, instead of making do and mending, these industries, with one significant exception, are likely in the future to decline. This one significant exception is that of research and experimental work, the making of prototypes, etc.

Important fields of economic activity in which an expansion of the demand for labour is possible are those of transport, retail trade, and entertainment. In retail trade, however, and to some extent in transport, this development would run contrary to the present tendency to increased mechanisation even in these fields (examples being the one-man bus and the self-service shop). It remains to be seen how much personal service the shopper desires. Perhaps in the distributive trades a sharp division may grow up between the distribution of standardised goods in highly mechanised self-service centres on the one hand, and the catering for particularly discriminating and choosy customers, who are willing to pay prices that involve an extravagant use of distributive labour, on the other. (It may be noted that the practice of retail-price maintenance is not favourable to such a revolution in methods of distribution.)

Another important field for expansion is that of personal service. If the benefits of automation are monopolised by a small rich class, then, in the absence of sufficiently high taxation, the labour made surplus in industrial employment will be absorbed into the personal service of the rich. We may thus see a striking tendency of the last 40 years moved suddenly into reverse. If the benefits of automation are more widely spread over the community, it is reasonable to suppose that there will be a big increase in services rendered to the community generally, such as those of teachers, doctors, dentists, nurses, etc. This may be possible under conditions of private enterprise; but it appears much more likely that the demand for such services can be effectively organised only through an expansion of the public social services, financed out of taxation.

(4) But let us return to manufacturing industry, particularly to those branches which are undergoing automation. We have seen that, except under rather special conditions, if the full effect of labour-saving is to be achieved, the automated industry must lose labour to others. But what of the labour that is left in it? The effect of automation is to shift the demand for labour so that, instead of a large and variegated labour force, a small but very specialised labour force is required. Fewer—much fewer—unskilled and semi-skilled workers, perhaps rather fewer highly skilled craftsmen, but many more high-grade technicians will be required. Doubtless many of the less skilled workers will find employment in other industries. But, if automation becomes at all general, there will be a big qualitative change in the direction of the demand for labour. The demand for intelligent and highly trained technicians will be very great, relative to the existing supply. (In fact, there will probably be a famine of labour of this type.) The demand for ordinary labour will fall. If the demand for ordinary labour from other industries does not expand quickly (and, given monopolistic policies on the part of either capital or labour, there are reasons for supposing that it may not), the aggregate demand in the country as a whole may well fall below the supply. In other words, a considerable amount of general unemployment may easily co-exist with a great shortage of highly specialised labour. This circumstance emphasises the importance of technical education and training. If automation is to come, we must get ready—now—to educate and train the specialised workers that it will need. Nay more, we must begin to educate and train those who will do the educating and training. The best preparation for automation is probably the expansion of our technical colleges and of their staff.

But, even if we do all that can be done in this direction, will it be possible to provide all the specialist labour that will be required? The answer to this question depends upon how educable the ordinary worker is, or, more precisely, what proportion of them are capable of being trained to do the new, specialised jobs. This is a field in which there is no knowledge, only opinion. In this country, with its reliance on traditional élites, both in the ruling class and in the ranks of skilled labour, there is a tendency to under-estimate the possibilities of raising the general level of technical skill over a wide range of the population. In both the U.S.A. and the U.S.S.R., where the climate of opinion is more equalitarian, a much more optimistic view of these possibilities is taken, and a much greater effort is made to produce a technologically literate population.

DISTRIBUTIONARY EFFECTS OF AUTOMATION

Automation involves changes in the relative intensity of demand for the various agents of production. As between capital and labour, it is likely to increase the demand for capital relatively to that of

labour. (Even if, as appears likely from some investigations that have been made, automation is capital-saving as well as labour-saving, it is the latter effect that is relatively most important. Although it may very well reduce the amount both of capital and of labour required to produce each unit of output, it is almost certain to reduce the latter much more than the former.) As between the different grades of labour, it is likely to increase the demand, relatively, for the highest grades of skill and reduce the demand, relatively, for practically all other grades.

(1) Capital and labour. In a purely *laissez-faire* economy, one would expect that the result of a shift in relative demand away from labour and towards capital would be to reduce wages relative to property incomes. (This does not necessarily imply an *absolute* reduction of wages: if the average level of the national income rises high enough, a reduction of wages relatively to profits may still leave the absolute level of wages higher than it was before.) One can envisage a community in which the combination of rapid technological progress and monopolistic control of output would divert a very large proportion of the national income into the pockets of the share-holding class, and in which unemployment would be combated by the development of habits of Babylonian luxury and profusion on the part of its recipients. Such an economy might be technically workable, but it would not commend itself to the moral judgment of the modern world. Any tendency of this kind would at once give rise to a politically irresistible demand for countervailing measures, such as more progressive taxation generally, the higher taxation of profits as such, and the nationalisation of industries in which automation was taking place or impending. If the State uses the proceeds of taxation in order to finance social services or income from civil rights (e.g., old-age pensions, family allowances, unemployment benefit), this will help to spread the benefit of innovation over a wider circle. If there is no spontaneous tendency to price reduction on the part of business firms, such a policy may be the next best way to spread the advantages of innovation over the entire economy and to promote a desirable expansion of demand.

(2) Different kinds of labour. It is almost certain that the forces of supply and demand will tend to raise the earnings of highly trained technicians and to depress, relatively at least, the wages of ordinary labour and also of the traditional crafts, which will no longer be in such strong demand. If, as a result of a rising real income all round (especially if general unemployment is successfully combated), the average level of real wages rises, the less skilled workers may not suffer an actual reduction in real wages but may only enjoy a less-than-average rise, while the earnings of the new technical élite soar to princely heights. But if our more pessimistic estimates of the possible expansion in the demand for labour are correct, the bulk of ordinary workers may face a reduced demand for their services, resulting in unemployment, or lower real wages, or both.

This brings up the political and social factor once more. With a trade-union movement like the British, whose numerical strength is now in the unskilled and semi-skilled *échelons*, and with a political labour movement that, in times of working-class prosperity, polls the votes of just under half the electorate, the probability is very high that the less skilled workers, forming the numerical majority of the population, will react violently against any tendency to put into reverse the equalitarian tendency in the movement of earned incomes that has shown itself so strongly during the last 15 years.

If labour is strongly organised in the automated industries, the workers (or some of them) may be able to appropriate for themselves a large part of the benefits of innovations. Two possible policies exist: they may demand the same wages and volume of employment as before, or they may demand the highest possible wages for a small number of workers.

(*a*) The first policy is that popular in British trade-union circles: viz., no redundancy, all displaced labour to be re-absorbed within the same firm. (This illustrates the old quip that British trade unions will always agree to the introduction of labour-saving machinery provided they can make it quite certain that no labour is in fact ever saved.) This means that the labour cost is the same as before automation. The only possibility of cost reduction (and hence of price reduction) is if the new process is capital-saving as well as labour-saving. Except for this possibility the result will be the old cost, the old price, no expansion in demand, and no general progress. The only beneficiaries will be the people who happen to be employed in the automated factory when automation is introduced ; they will receive the same pay for a fraction of the work.

(*b*) An alternative policy (more in line with American trade-unionism) would be not to oppose technological redundancy, but demand the highest obtainable wages for those workers who were retained. In this case, again, the wages bill would be kept at its old figure, with corresponding little chance for price-reduction and output expansion; but from the workers' point of view the result would be a small number enjoying extremely high wages and a much larger number thrown upon the labour market. If the rest of the economy was buoyant, with large investible funds forthcoming to finance new industries, the displaced workers might be re-absorbed, but not at the high wages of the lucky few.

Both policies on the part of organised labour are likely to lead to glaring inequalities as between different bodies of workers in the same industry—inequalities of leisure in the one case, inequalities of pay in the other case. Even if an entire industry were automated, a wages policy of this kind would create glaring inequalities between workers in automated industries and workers in other industries, which had either not yet been automated, or where automation was in the nature of things impossible. (This last, as has been seen, is an important category.) This tendency to increased inequality between workers in different industries or between employees of different firms would be intensified by any general introduction of profit-sharing or co-partnership schemes, or even of a guaranteed annual wage on the model now popular in the U.S.A.

This aspect of the subject was brought home to me very clearly on seeing one of Rene Clair's films, *A nous la Liberté*. At the end of the film a gramophone factory had been completely automatised and the factory owner, having got into difficulties with the police (for reasons quite unconnected with automation), disappeared, after handing over the title-deeds of the factory to the workers in it. The last sequence of the film showed the younger workers dancing happily in the open air while the older workers fished peacefully in the river. All the while there poured forth from the factory hundreds and hundreds of neatly packaged gramophones in the production of which no human being had done a single hand's turn. "How delightful" was the spectator's immediate response. "What about the workers in the other factories?" was the slightly delayed reaction of at least one spectator.

NEW BOOKS

Some of the books noticed here are selected for extended review in ENGINEERING.

Design of Heating and Ventilating Systems. By F. W. HUTCHINSON. *The Industrial Press*, 93 *Worth-street, New York* 13, *N.Y., U.S.A.* (7 dols.); and *Bailey Brothers and Swinfen, Limited*, 46 *St. Giles High-street, London, W.C.*2. (60*s.*)

This book deals primarily with engineering science as applied to system design and is intended, therefore, to supplement rather than replace standard text-books in this field. Considerable space is given to panel heating, solar heating, and airway design. The book is divided under such chapter headings as load determination (under various conditions), fuel and combustion, air distribution, and design procedure for different types of heating. Basic handbook data is included so that situations can be analysed by the insertion of field data.

A.C. Switchgear. Vol. I: A Survey of Requirements. By J. R. MORTLOCK. *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.*2. (50*s.*)

The purpose of this book is to give some guidance to system engineers regarding the problems associated with the determination of switchgear ratings. It is not intended as a design manual, since such matters as the choice of protection and the determination of re-striking transients and insulation levels are mainly the province of experts. To segregate a faulted current, however, it is essential that its location should be determined and, consequently, the basic principles of different types of protection and relays are considered. To ensure correct operation of the protective gear the measurement of fault currents and voltages is essential, and the performance, under these conditions, of the normal devices for doing this is treated.

The remainder of the book is concerned with the voltage aspect of the problem. Primarily, some consideration is given to the phenomena associated with the initiation of arcs. This leads to the concept of re-striking voltage and guidance is given to its determination in simpler cases. Finally, the question of insulation level, which at the higher voltages to a large extent governs the cost of installation, is treated.

The details of switchgear and the basic principles of its design will be dealt with in a second volume.

Frequency Modulation Engineering. By CHRISTOPHER E. TIBBS and G. G. JOHNSTONE. Second edition revised. *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.*2. (45*s.*)

This book is intended to provide students and engineers with a concise survey of the whole field of frequency modulation engineering. Since the first edition was published in 1947, there have been considerable additions to the literature of the subject and this has meant substantial alterations to the book, for which the second author has been largely responsible.

The Weldability of High-Tensile Structural Steels. By C. L. M. COTTRELL, K. WINTERTON and B. J. BRADSTREET. *British Welding Research Association*, 29 *Park-crescent, London, W.*1. (20*s.*)

The work described in this report was undertaken during the period June, 1948, to May, 1954. The report details the work undertaken on the welding of high-tensile steels on behalf of the Ministry of Supply and is largely a chronological account of the development of the British Welding Research Association' scontrolled thermal severity test for the assessment of weldability, the use of continuous cooling transformation data in the correlation between weldability and composition, and the application of these tests to a number of selected steels of various types.

The Control of Quality in the Production of Wrought Non-Ferrous Metals and Alloys. III: The Control of Quality in Heat-Treatment and Final Operations. Institute of Metals Monograph and Report Series No. 17. *The Institute of Metals*, 4 *Grosvenor-gardens, London, S.W.*1. (15*s.*)

This monograph consists of a reprint from the *Journal* of the Institute of Metals of a symposium of papers, Nos. 1589 to 1594, with the discussion upon them. The six papers all deal with the control of quality, heat treatment and final operations in the production of wrought aluminium, copper, nickel and other non-ferrous metals and alloys. Part I of the symposium, on "The Control of Quality in Melting and Casting," was published as Monograph No. 15, 1953, and Part II, on "The Control of Quality in Working Operations," as monograph No. 16, 1954.

Structural Aluminium. *Northern Aluminium Company, Limited, Bush House, Aldwych, London, W.C.*2. (Gratis.)

Founded on well-established data, combined with the results of a great deal of research, this cloth-bound volume of 150 pages sets out not only to familiarise the structural engineer with aluminium as a material, but to present a design method which experience has shown to be reliable.

Many of the data are given in tabular form and these include details of the efficient structural sections developed for aluminium. Notes on welding, riveting, corrosion resistance, and fabrication are also given.

Iron and Steel To-day. By JOHN DEARDEN. Second edition. *Oxford University Press* (*Geoffrey Cumberlege*), *Amen House, Warwick-square, London, E.C.*4. (12*s.* 6*d.*)

The author gives a broad and general outline of iron and steel metallurgy from the smelting of the ore to the production of the many grades of steel required by modern industries.

Although not specifically intended for the fully-qualified ferrous metallurgist, it contains much detailed technical information and should be of value to metallurgical students, non-ferrous metallurgists, engineers and designers, and also to such persons as works engineers, storekeepers, inspectors, transport managers, welfare officials and others employed in branches of the industry not actually concerned with the production or shaping of iron and steel.

Upwards of 40 half-tone plates, 34 line drawings and many tables of data are included.

The Diecasting Process. By H. K. BARTON. *Odhams Press, Limited*, 96 *Long-acre, London, W.C.*2. (21*s.*)

The aim of the author has been to provide detailed and up-to-date information for the guidance of all persons engaged in making, purchasing or using die castings. The various chapters deal with such matters as dies and machines for the production of die castings, fettling and machining operations, surface finishes, assembly and attachment methods, production techniques, designing for die casting, the purchasing of die-cast components, and the organisation and layout of a die casting plant.

TEST INSTALLATIONS ON AN EARTH-FILL DAM

The Flood-Control Act of 1944, which embodies recommendations made by the Bureau of Reclamation of the United States Department of the Interior, covers reclamation and development on the Missouri River and its tributaries. The control of the flow of the Republican River, one of the tributaries, forms an important item in the whole project. This river flows through the south-eastern part of the State of Nebraska and its basin has many times been subjected to serious flooding. Among the control works planned was the construction of a dam on Medicine Creek, a tributary of the Republican River, resulting in the formation of the Medicine Creek Reservoir with a capacity of 18,000 acre-feet. Besides eliminating flooding, the regulation provided by the reservoir permits the controlled irrigation of more than 50 thousand acres of land.

MOST SEVERE CONDITIONS

A detailed account of the design and construction of the dam is given in a report of which particulars will be found in an earlier issue of ENGINEERING (vol. 180, page 560, 1955). A feature of the dam of considerable interest is the elaborate series of test installations which have been incorporated in it to measure any settlement or displacement. Before dealing with this, a general description of the dam and its method of construction is desirable. It is a rolled-earth structure with a crest length of 5,665 ft., this figure including 582 ft. of dike section and 229 ft. of spillway section. The dam contains a total of 2,676,400 cub. yards of material.

The height above the lowest foundation excavation is 165 ft. and the height above stream bed 115 ft. The crest is at elevation 2415, and the upstream face of the dam, above elevation 2335, is blanketed with rip-rap, the downstream face being protected from erosion by a 12 in. gravel blanket. The spillway in the east abutment is a concrete structure containing four 50 ft. wide ungated openings with crests at elevation 2386·2 and a 13 ft. centre notch at elevation 2266·1. Flood records indicated that in the most severe conditions the water in the reservoir would rise to elevation 2408·9. Under these conditions, the discharge over the spillway would be 97,800 cub. ft. per second. The 50 ft. spillway openings are separated by piers which carry a highway bridge.

When the reservoir level stands at the elevation of the main spillway crest, the 13 ft. centre notch will discharge 4,000 cub. ft. per second which is the safe channel capacity of the river below the dam. The outlet works, situated in the west abutment consist of a inlet track structure, at elevation 2335, a vertical shaft and a horseshoe-shaped conduit with a gate chamber and a control house at the downstream toe of the dam. The discharge is controlled by hydraulically-operated valves. The arrangement is designed to discharge 300 cub. ft. per second of irrigation water when the reservoir level stands at elevation 2343.

HORIZONTAL SEDIMENTATION

The geology of the area in which the dam is situated is relatively simple. The sedimentation is nearly horizontal and there is little faulting. Niobrara, a white or yellow chalk grading downwards to a grey chalky shale, covers the entire area and forms the bedrock of the dam. The river valley is covered with recent alluvial deposits consisting of silts, sands and gravels. On the edges of the valley and the higher surrounding land these deposits are overlaid by loess, a wind-deposited fine silty to clayey loam of moderately low density. Ogallala, a conglomeratic sandstone, containing pebbles of limestone and granite, was found in some of the excavations for the dam, particularly in the spillway and outlet works areas. The site of the dam was chosen to take advantage of solid foundation, on the west abutment, for the location of the spillway.

Initial boring investigations were undertaken to determine the nature of the formations underlying the site and to locate the sources of materials suitable for incorporation in the dam. Much of the material recovered in the excavations for the foundations and outlet works was found to be usuable but this was supplemented by material obtained from two quarries and a borrow area which were opened in the neighbourhood. The chalky shale underlying the whole area is impervious and grouting was deemed unnecessary. There were, however, pervious zones in the alluvium underlying the river bed and it was necessary to construct a cut-off trench. It is located about 90 ft. upstream from the crest of the dam.

CORE

Fig. 1 is a cross section of the dam, showing the materials of its construction. It is divided into four main and two auxiliary zones, zone 1 constituting the centre impervious core, and including the cut-off trench, is made up of silty loose soil obtained from the borrow area and the rock quarry area. The material weighed about 80 lb. per cub. ft. when placed but this was increased to 105 lb. per cub. ft by conditioning, blending and tamping. It was placed by 17 cub. yard bottom-dump trucks and spread to 10 in. lifts by a bulldozer and motor grader. Water was then added by water wagons, to bring the moisture content up to approximately 12 to 16 per cent., after which the material was processed by scarifying and rolling. The final operation was consolidation by tamping rollers loaded to a weight of 48,000 lb. About 12 passes of these rollers reduced the 10 in. lift to 6 in.

Zones 2, 2A and 2B are made up with material from the spillway and outlet works excavations and from one of the quarry areas. This material is more pervious than that of zone 1 and contains rocks up to 10 in. in diameter. It was spread in 1 ft. lifts (3 ft. lifts in zone 2B) by a bulldozer, watered and compacted by tamping rollers weighing 40,000 lb. Zones 3 and 4 contain material from the various foundation excavations. It is more pervious than the materials of zones 1 and 2. It was hauled by dump trucks and spread by a bulldozer and grader to 2 ft. lifts. Compacting was obtained by routing the hauling equipment over the lifts.

PORE-WATER PRESSURE

The test apparatus which has been built into the dam records pore-water pressure in the embankment and foundations and the extent of settlement or displacement. Pore-water pressure is recorded by a piezometer installation, the pressures in the embankment being transmitted through water-filled tubes to two terminal wells located on the downstream slope of the dam; the pressures are indicated on gauges. The readings enable the extent of saturation, the percolation stream lines and the uplift to be determined.

PIEZOMETER TIPS

There are 64 piezometer tips installed in the dam, with 36,000 linear feet of ¼ in. plastic tubing connecting them to the terminal wells. The tips and tubing were placed in their required positions as the construction of the dam proceeded. They are installed at various levels; the highest is at elevation 2371·1, the crest of the dam being at elevation 2415. The method of installation, which was the same throughout, may be described for the foundation tips. A hole was wash-bored to the shale and provided with a 2 in. casing. A ¾ in. pipe was then prepared by capping one end and drilling twelve ¼ in. holes in a 1 ft. space situated, depending on the particular installation, 3 in. to 15 in. above the capped end. The pipe was then filled with sand which passed a No. 4 screen but was retained on a No. 14 screen. This prepared pipe was then lowered into the cased hole and additional lengths of pipe were coupled on until the capped end of the pipe rested on the shale at the bottom of the hole. Each additional length of pipe was filled with sand after it was coupled in order to eliminate the possibility of coarse grains of sand forming a plug. A short-pipe was then placed in the hole with the bottom at the required elevation. It was drilled and capped in the same manner as the longer extension and was filled with sand of the same size. The short pipe was taped and wired to the longer pipe to keep it at the required elevation. The top of one of the two pipes was left at a higher elevation than that of the other to facilitate attachment of the caps. The space between the ¾ in. pipe and the 2 in. casing was filled with dry sand after the pipes were capped.

This description applies to a number of tip installations. After they were made, approximately 2 ft. of embankment material was placed over the caps. A trench was then dug by a trenching machine to accommodate the plastic tubing connecting the tips with the terminal wells. The bottom of the trench was approximately 3 in. below the desired elevation of the tubing. It was backfilled to a depth of 3 in. with material passing a No. 4 screen and was hand graded with a rake to a grade of 0·5 per cent. sloping upwards towards the terminal well entrance. In forming the trench, the material above the pipe caps was excavated by hand. The length of plastic tubing necessary to reach the terminal well was then estimated and the necessary lengths were cut off, marked every 25 ft. with the tip number and coiled in pairs.

CUT-OFF PLUG

The piezometer tips were then placed in position on the pipe extensions and the tubes extending from the tips were laid in the prepared trench. The trench contained 40 tubes and these were arranged in two layers with some 3 in. of fine material between them. The whole was

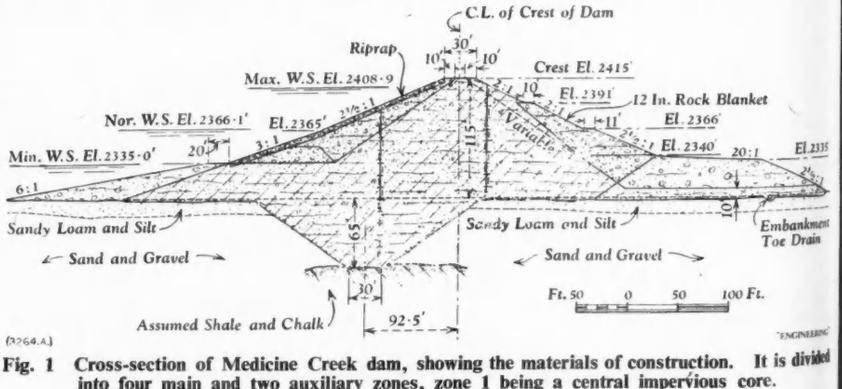

Fig. 1 Cross-section of Medicine Creek dam, showing the materials of construction. It is divided into four main and two auxiliary zones, zone 1 being a central impervious core.

covered with 6 in. of similar material before the trench was filled in. To prevent flow of water between the tubes and the compacted material of the dam, a cut-off plug consisting of zone 1 material mixed with 5 per cent. bentonite was used in the trench. The entrance pipe of the terminal well is at elevation 2320, some 20 ft. below the downstream surface of the dam at the position of the well. The trench leading to the entrance pipe was backfilled before resumption of embankment placement operations. A similar procedure was followed in placing piezometer tips which occupied positions higher up in the embankment.

SETTLEMENT INSTALLATIONS

There are three types of settlement installation respectively covering embankment settlement, foundation settlement and surface settlement. The embankment settlement installation consists of four assemblies of telescoping 1½ in. and 2 in. pipes, some 3 to 4 ft. long, the 1½ in. pipes being anchored in the embankment by means of cross-arms. The arrangement is shown in Fig. 2 below, and two are indicated by the vertical lines on the cross-section of the dam. Two are on the upstream side of the crest and two on the downstream side. The telescoping arrangement allows any anchored pipe section to move independently the others. The two upstream installations have, respectively, 25 and 27 cross-arms and the downstream ones each 20. Any settlement will alter the position of one, or more, of the cross-arms and the original positions being known, settlement may be determined.

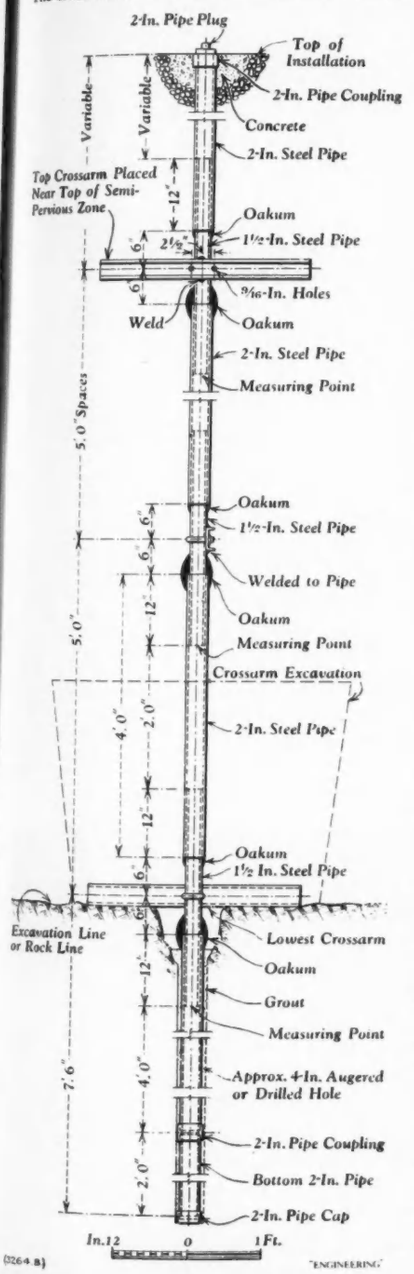

Fig. 2 Typical embankment settlement installation. Four such assemblies of telescoping pipes are used and allow any anchored piped section to move independently of the others.

"TORPEDO"

Measurements are made by means of a steel tape carrying what is termed a "torpedo" at its bottom end. This is lowered into the telescoping pipe and at the selected depth at which a reading is to be taken is drawn upward when two pawls carried by the torpedo engage the lower end of the 1½ in. pipe carrying the cross-arm. Measurements are taken on a scale clamped to the projecting end of the telescoping pipe on the top of the dam and with a 25 lb. pull on the tape. When a measurement has been taken, the tape is lowered to the bottom of the telescoping pipe, where the torpedo strikes a latching plate which releases the pawls and allows the tape to be withdrawn. The operation may then be repeated for a cross-arm at a different level.

The lowest cross-arm of the upstream installations were placed on the shale at the bottom of the cut-off trench. A 3 in. hole was drilled approximately 8 ft. deep into the shale and plugged. When backfill operations had reached an elevation which would cover the top of the 1½ in. pipe of the cross-arm to a depth of about 18 in. a 2 ft. by 4 ft. excavation was made to the shale surface and the plug removed. The 2 in. pipe with the latching plate was then placed in the hole with the top approximately 6 in. below the bottom of the cross-arm. The 1½ in. pipe was then placed in position with the cross-arm resting on the shale; oakum was wrapped and wired in place around the pipe at a point some 12 in. below the top. The bottom of the next 2 in. pipe section was seated on this oakum, ensuring that it occupied the correct position. Oakum was also placed around the joint between the top of the lower 2 in. pipe section and the 1½ in. cross-arm pipe section. Compacted backfill was then placed over and around the cross-arm. A temporary cover was placed on top of the projecting 1½ in. pipe before the placing of dam material continued.

A procedure similar to the above was followed in placing the cross-arms higher up in the dam. As construction proceeded and the embankment reached an elevation approximately 5 ft. above the position of the previous installation, a trench some 2 ft. by 4 ft. was made in the rolled fill at the position of the telescoping pipe to a depth some 3 to 6 in. above the elevation at which the cross-arm would rest. The remainder of the material was then carefully removed by hand, the purpose of this procedure being to ensure that the cross-arm rested on undisturbed rolled fill. The elevation of each cross-arm was determined in relation to bench-marks which were set by the survey party at the time the installation was set up. The position of each cross-arm was checked each time that a further cross-arm had been installed.

COMPUTING PLATE SETTLEMENT

The foundation settlement installations are located 20 ft. upstream from the dam axis. They consist of a 2 ft. by 2 ft. ⅜ in. thick steel plate with a 6 in. length of 1 in. diameter pipe welded at the centre. Four triangular steel sections, welded to the pipe and plate serve as braces. A cap was placed on the top of the pipe. When the embankment had reached an elevation approximately 2 ft. above the foundation stripping line, a survey party located the position of the base-plate. A 2½ ft. by 2½ ft. pit was then excavated to the stripping line and the bottom was levelled on the undisturbed foundation material. The plate was then placed in position and the pit filled in and compacted by hand. The placing of embankment material then proceeded and when a height permitting a 4 ft. length of pipe to be connected to the plate pipe, plus 1½ ft. of cover over the top, a hole was augured to the cap of the plate pipe and the 4 ft. length of pipe added. The exact length of this pipe was carefully measured and a coupling was screwed on to its lower end. As it was essential that the ends of the two pipes should be in close contact, the coupling was provided with an exceptionally deep thread ensuring that there should be no binding and that the pipe ends were really in contact. The amount of plate settlement could be computed by adding the length of the installed pipe sections to the original elevation of the plate and relating this figure from the elevation of the top of the added pipe.

SETTLING UPWARDS

The above procedure was repeated as the embankment was gradually built up but as the upper pipe extension passed through 1 ft. of rock blanket and 2 ft. of heavy rip-rap it was not possible to use an auger to expose the buried pipe cap. Accordingly, a 2 in. pipe, approximately 5 ft. long, was slipped over the 1 in. pipe and set in the embankment to a depth of about 1 ft. The capped end of the 1 in. pipe extended some 4 or 5 in. beyond the 2 in. pipe. A concrete collar was then placed around the 2 in. pipe, the arrangement protecting the 1 in. pipe and leaving it free to settle. Readings were taken each time that a pipe extension was added and after the third and fourth pipe sections had been installed it was found that the base-plate rested at a higher elevation than when it was first placed. This phenomenon was attributed to the fact that embankment material upstream of these installations was placed first, the heavier loading on part of the foundations causing displacement and rise of the more lightly loaded section. The rise continued until it was checked by placing embankment fill over the settlement installations.

The surface settlement installations consist of ¾ in. round steel bars, 3 to 5 ft. long, driven into the embankment, and capped with concrete. The bars project 1 to 3 in. above the concrete, and have intersecting lines filed on the ends for measurement purposes. There are in all 73 surface settlements points arranged in five lines and at 200 ft. centres. Two lines of points are, respectively, 15 ft. upstream and downstream from the axis of the dam. The other three are 155 ft. upstream, 125·5 ft. downstream and 297·5 ft. downstream.

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EXTENSIONS TO BRIGHT-ANNEALING PLANT FOR COILED STEEL STRIP

Eight new vertical cylindrical furnaces have recently been added to the plant installed at the Courtybella Works, Newport, Monmouthshire, of the Whitehead Iron and Steel Company, Limited, for the bright annealing of coiled steel strip. The first furnaces were installed some 20 years ago and the plant now totals 37 furnaces and 248 annealing containers, and all of these were designed and supplied by the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2.

The eight new furnaces are each rated at 150 kW and take containers having effective internal dimensions of 44 in. in diameter and 86 in. in depth. The furnaces are heated by heavy-gauge nickel-chromium wire elements arranged in coil form and placed circumferentially round the inside wall of each furnace in grooved refractory material.

A controlled artificial-gas atmosphere, generated from ordinary town gas, is used to maintain the bright finish on the steel surface, and this is supplied from a central gas station. The total atmosphere consumption for the complete installation, is some 4,500 cub. ft. per hour.

Fig. 1 The two assembly lines run side by side and are connected at the painting booth by a cross conveyor which also raises the implements so that they can be hung on the overhead line.

PAINTING AND POLISHING

TECHNIQUES AND PLANT AT PLOUGH WORKS

In a recent issue we published a note on the Nacton Works of Ransomes, Sims and Jefferies, Limited, Ipswich (issue of June 1, page 422). During the course of it, mention was made of two items of particular interest, the flow coat painting system and the mould-board grinder. Some additional details of these items have now been obtained and are given in this article, beginning with the painting installation.

The assembly of the various components that make up the different agricultural implements made at the Plough Works is accomplished on two conveyor lines, one of which is a floor drag type conveyor, the implements being assembled on trolleys; this line is used for a very wide range of wheeled implements. The second assembly line, which runs parallel to the drag conveyor line, is of the slat type and is used for the assembly of mounted implements, i.e., implements which are mounted directly on the hydraulic lift attachment of a tractor.

The original decision was for all agricultural implements from the works to be spray painted, but in view of the heavy paint wastage which would ensue from the type and the tremendous variety of work to be handled, alternative methods of painting were considered, and as a result of experimental work carried out it was finally decided that a single flow coat line should be installed.

One problem was to connect two dissimilar assembly lines on to a common painting line, and this was overcome by designing a transfer conveyor running at right angles to the lines and containing a wheeled bogie on which the implement to be painted could be transferred, either complete with its trolley in the case of wheeled implements, or by means of a roller conveyor in the case of mounted implements. The transfer bogie is shown in Fig. 1.

The loading conditions opposite each assembly line differed in that for the wheeled implements the trolleys were at shop floor level, while in the case of the mounted implements, the assembly conveyor stood proud of the shop floor by some 12 in. It was also necessary to have some means of lifting the traversing trolley on the transfer conveyor to enable the implement to be painted to engage with an overhead Monorail system.

At each end of the traverse of the transfer conveyor, therefore, a hydraulic lifting system was provided arranged for remote operation from a control panel, so that the traversing trolley could be raised in order to permit the implement being painted to be hung from the overhead conveyor system.

The size of the work to be treated varies from the smallest implement having an approximate 3 ft. cube size, and weighing a few hundredweights, up to large ploughs built for the export market which may have a width of 12 ft., an overall height of some 6 ft., and an overall length of 23 ft. and weigh approximately 3 tons. It was decided, when designing the Monorail conveyor system, that each load trolley should be capable of carrying a maximum load of one and a half tons, and that when handling the largest work it should be suspended from two load trolleys.

The painting conveyor system, as finally installed, comprises an endless Monorail system, having an approximate length of some 210 ft., which is provided with articulated load and chain trolleys at 4 ft. intervals throughout the entire length; the implements are suspended from the load trolleys by forged link chains, a three-point suspension being adopted for the majority of work to be processed. In order to attain the output required, the painting conveyor is designed to have a speed of 200 ft. per hour.

As a result of the experimental work conducted on a pilot flow coating unit, it was decided that the length of the actual flow coating section should be equivalent to two minutes' travel time of the conveyor system and, to ensure complete coverage of articles of widely differing shape and size, that the flow coating jets should be arranged to encircle completely the work to be painted. The arrangement of the flow coating rings is shown in Fig. 2, which shows an implement passing through the jetting zone. As a result of actual working experience, it has been found that complete coverage can be obtained by jetting from the bottom only, and so the side and top jets are not normally used.

PAINT RECIRCULATED

As there was no working experience available on this method of painting and on this type of equipment, considerable discussion between the paint suppliers, Lewis Berger and Sons, Limited, 35 Berkeley-square, London, W.1, and the plant designer ensued in order to overcome at the design stage as many of the difficulties which might arise when the plant was put into production as could be envisaged, and much useful information was obtained from the pilot plant set up at Ransomes' works in conjunction with Stordy Engineering, Limited, Cumbria House, Goldthrone-hill, Wolverhampton.

The flow coating chamber comprises a Terrazzo type draining slab surrounded by a steel sheet housing, the working sumps to which the excess paint flows back being located in a tank room immediately below the flow coat chamber proper. The main circulating pump, which is of the screw pattern, and fitted with a relief valve, has a maximum capacity of 300 gallons (although in actual working conditions 150 gallons are sufficient) per minute, and the pipework in the tank room is so arranged that the pump can draw from either settling tank, duplicated for maintenance purposes, or from a solvent tank which is used for cleaning down during maintenance periods or at the end of each shift. The drain from the flow coating section is also interconnected and valved so that any of the three tanks can be brought into service.

On the suction side of the main pump there is fitted a self-cleaning filter, and in order to keep the large paint volume in condition during long shut down periods, a subsidiary pumping set, having a capacity of 20 gallons per minute, has been provided, piped and valved generally as for the main pumping system, and also with a connection to enable paint to be discharged at floor level should this be required.

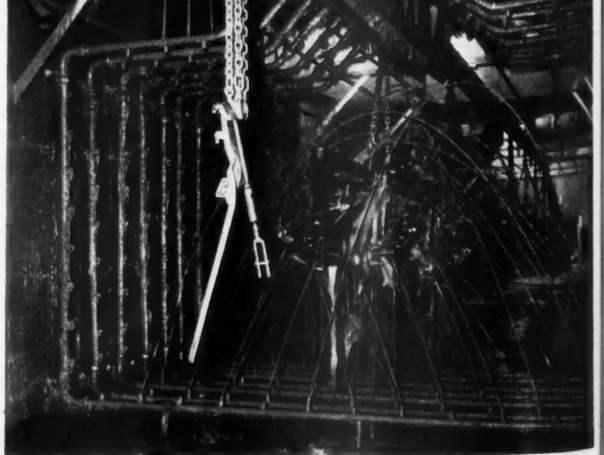

Fig. 2 In the flow coat system, paint is sprayed from jets over the implement. It has been found that the floor jets are usually sufficient, although both side and top jets were provided. The paint draining back is recirculated.

Each of the main settling tanks has a capacity of some 1,200 gallons, and the solvent tank of some 600 gallons; from actual experience, however, it has been found that only 600 gallons of paint are necessary for normal working conditions. The tank room was designed so that a second set of similar equipment could be installed at some later date, if required. In order to keep a fresh atmosphere in the tank room, an exhaust duct system is provided with an exhaust fan mounted above the roof of the flow coat section proper; also the room is heated in order to maintain, in so far as is possible, a constant viscosity in the main paint volume.

DRAINING AND DRYING

After leaving the flow coat section proper, a complete enclosure is provided, equivalent to a travel time of about 20 minutes. In order to give good flow-out, the first seven-minute length of the drain section is arranged as a solvent chamber. Exhaust ducting is provided at the entry end of the flow coat section, and also at the end of the solvent vapour section; each of these duct systems couples back to a multivane centrifugal exhaust fan which discharges to the outside atmosphere. It has been found that under working conditions, by adjusting the duct settings, that spillage of solvent from the flow coating booth into the surrounding shop space is completely prevented.

At the end of the flow coating section, the overhead conveyor system dips in order to deposit the painted implement on to a wheeled truck for transfer to the stoving oven. The painting conveyor then returns alongside the flow-coat booth, the chains which have supported the implement in its passage through the painting section being cleaned off in a solvent tank during their passage back. The drying oven has a working temperature range of up to 400 deg. F., though under normal working conditions the operating temperature is usually between 230 deg. and 250 deg. F. Travel time through the oven is 18¾ minutes. After leaving the oven, the implements are discharged from the load trolleys and are hung on a transfer conveyor which takes them to the dispatch department at the end of the works, which has its own loading bays and railway siding. Parts for export are cased before reaching the loading deck. The assembly conveyors, and also the warehouse conveyor system were installed by Bagshaw and Company, Limited, Dunstable; the transfer conveyor system complete with hydraulic lifts, the painting conveyor, flow coating installation and drying oven with conveyor were all designed and installed by Stordy Engineering, Limited.

POLISHING MOULD BOARDS

The second of the two items is the machine for grinding and polishing the mould boards or bodies of the ploughs. It was developed by the firm following the last war, mainly as a result of the acute shortage of labour. A prototype was designed and built by the jig and tool department and proved satisfactory during two years trials. At the conclusion W. H. A. Robertson and Company, Limited, Lynton Works, Bedford, undertook production of the machine. Fig. 3 shows one of the production models in operation. Previously the work had to be fed under the wheel by hand.

The main difficulty involved in the operation is the variety of contours that have to be accommodated, coupled with the fact that bodies of the same type cannot be brought to a common contour due to a slight distortion of the ¼ in. thick plate; instead, a cut of equal depth has to be taken across the existing contour. The approximately helical, convex or concave form has at all times to be presented normal to the wheel; the stroke of the machine table has to vary automatically to cover the whole surface, and the cross-feed rate has to vary proportionally to the length of stroke.

The machine consists of six main parts: a main bed; a carriage to provide cross feed; a main traverse table; a pivotally mounted work table; a column for wheel head with means of height adjustment; and a wheel head which is pivotally mounted in the column. The polishing wheel, which is driven by a 5 h.p. motor, is made of stitched canvas and the outer periphery is coated with abrasive. The bearing housing is pivoted to allow the spindle to swing in a vertical arc during operation, and a hydraulic cylinder exerts a downward force to maintain wheel contact with the workpiece. The adjustable head column resembles that of a normal grinding machine.

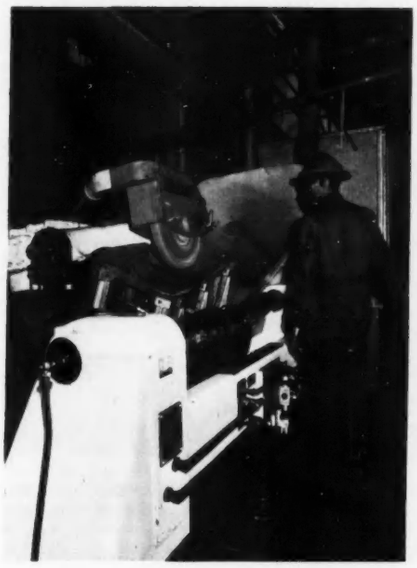

Fig. 3 The awkward contours of a plough body or mould board can be ground and polished by a specially designed machine.

The cross-feed carriage runs on V and flat guides on the machine bed, and is moved by a hydraulic cylinder through a speed control valve. A varied rate of feed, according to the length of stroke of the main table, is produced by a cam mounted on the carriage which controls the setting of the valve.

The main table is mounted on the carriage as in standard machines and is driven by a double-acting hydraulic cylinder. Mounted on this table are two brackets, one at each end of the table, which carry the bearings for the work table, the support bar for the tracing valve, and the oil cylinders that control the swinging movement of the work table. The spool of the tracer valve is in contact with a straight bar supported by two plungers mounted on the carriage; the lower ends of these plungers rest on cams on the main bed. Thus, as the carriage is fed across, the level of the crossbar can be varied and this, in turn, varies the movement of the tracer valve spool which controls the amount of swing of the work table.

The surface of the main table also carries a plate, cut to a predetermined profile, on which run the switches which operate the table reverse valves. The form of the plate is so made that as the edge of the plough body moves under the centre of the polishing wheel, the direction of stroke of the main table is reversed. Between the two reversing switches is a third switch which shuts the machine off if either reversing switch fails and the wheel goes over the edge; it thus acts as a safety precaution. The machine is arranged with push-button controls, the buttons being housed in a pendant. The electro-hydraulic equipment is contained in two cabinets remote from the machine. Each machine is equipped with a dust exhaust unit coupled by flexible hose to the work table.

UNIFORM CASE HARDENING

Nitrocycle Closed-Retort Process

A method of nitriding developed during recent years by the Oil Well Supply Division of the United States Steel Corporation, Oil City, Pennsylvania, U.S.A., has been given the name of the Nitrocycle process of case hardening. In this process the nitriding is carried out in a closed system, hence any heat-treating furnace capable of maintaining a controlled temperature of 1,000 deg. F. may be employed and gas-circulating fans are not required to produce uniform results.

Briefly, the new process takes advantage of the fact that molecular nitrogen and molecular hydrogen, when heated under pressure in the presence of a catalyst, such as iron, will unit to form ammonia. These conditions are met in a closed system if a sufficient quantity of ammonia is charged with the work, is not allowed to escape, and is heated to the nitriding temperature of between 950 and 1,050 deg. F. The ammonia not only dissociates and makes atomic nitrogen available, which combines with various elements at the surface of a nitriding steel to form very hard nitrides, but that portion which becomes molecular nitrogen (N_2) recombines with the molecular hydrogen (H_2) also present to re-form ammonia.

The cycle is repeated until a large percentage of the original ammonia is utilised in the formation of nitrides.

Low-carbon steel retorts have proved satisfactory and even after 20 or more experiments have been found to be little embrittled. They are introduced into a gas-fired furnace, and one retort, capable of containing 72 small piston valves made of 1 per cent. aluminium-chromium-molybdenum nitriding steel, was used 50 times without leaking or needing repairs. In these experiments an ammonia pressure of 400 lb. per sq. in. at the nitriding temperature yielded approximately 5 grammes of ammonia for each square foot to be nitrided, and 15 hours at 1,000 deg. F. produced a case, on the steel surfaces, of 0·015 in., with 0·008 in. of it having a hardness in excess of 700 Vickers pyramid numbers.

The nitriding of the interior surface of tubes or cylinders is best accomplished through the use of a measured amount of liquid ammonia in individually-sealed capsules, a refrigerator being utilised for filling the capsules. These have a small drilled hole and this is plugged by a low-melting-point solder. The ammonia capsule is slipped into the steel tube to be nitrided and the tube closed by means of welded end plates or plugs. As the tube is heated in the furnace, the soft solder melts and the liquid ammonia vaporises and performs its task in the tube interior.

With such work as can best be handled in a closed retort, however, it is usually more convenient to employ gaseous ammonia, determining the amount present by pressure measurement.

Further information regarding the process and other matters relating to it can be obtained from a United States Corporation subsidiary company in this country, Oil Well Supply Company, Limited, 5 Queen-street, London, E.C.4.

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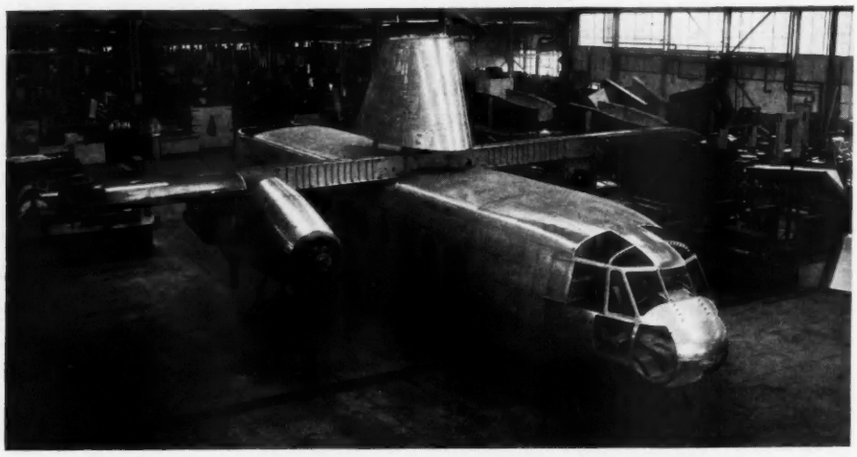
APPOINTMENTS AT R.A.E. FARNBOROUGH

The Ministry of Supply have announced that three appointments have been made at the Royal Aircraft Establishment, Farnborough.

Mr. E. C. Cornford, B.A., is to be head of the guided weapons department. Mr. D. J. Lyons, B.Sc., is to be senior superintendent, ballistic missiles division of the guided weapons department, and Mr. P. A. Hufton, M.Sc., senior superintendent, supersonics division of the aerodynamics department. They have all been promoted to the rank of deputy chief scientific officer.



In the Rotodyne, now being assembled at Hayes, the wing, engines, undercarriage, fuel tanks and rotor assembly form a single lifting and propulsion unit to which various fuselage forms can be attached.

The fuselage of the prototype Rotodyne is 8 ft. wide and 6 ft. high and has large clamshell doors at the rear through which vehicles can be driven and other bulky freight can be readily loaded. As a passenger machine, 40 seats can be provided.

PROGRESS WITH THE ROTODYNE

RAPID AND ECONOMICAL INTER-CITY TRANSPORT

The construction of the prototype Rotodyne helicopter, designed to carry 40 passengers over inter-city air routes of up to 400 miles, is now well advanced at the works of the Fairey Aviation Company, Limited, Hayes, Middlesex, and it is expected to make its first ground runs before the end of the year. If the performance comes up to the expectations of its designers and constructors—and when the initial operating and maintenance problems that are bound to arise with a new concept have been smoothed out—Great Britain will be able to offer to the world's airlines a helicopter that will be, for the first time, truly competitive in cost with the fixed-wing machine over short distances of up to about 150 miles.

The Rotodyne, it may be recalled, has a single reaction-driven four-blade 90 ft. diameter rotor and a fixed wing on which are mounted two Napier Eland N.El.3 propeller turbines each developing 3,000 e.h.p. In cruising flight, all the power of the Elands is directed to driving the propellers, and the machine is sustained in the air partly by the lift of the fixed wing and partly by auto-rotation of the rotor. By this means it is possible to cruise much faster than on a pure helicopter in which all the lift and all the propulsive effort is provided through the rotor.

For take-off and landing, on the other hand, most of the power of each Eland is directed, through a hydraulic clutch, to drive air compressors supplying air at four atmospheres and a temperature of 160 deg. C. through the hollow rotor blades to pressure jets at the blade tips in which kerosine is burnt. In this condition, the propellers are used solely for providing directional control at low forward speeds. Transition from the take-off to the cruising regime, is accomplished by increasing the forward speed, still operating as a helicopter, and increasing the airscrew pitch, to give forward thrust, then shutting off the tip jets and declutching the compressors. This has been proved successfully in flight trials on the Jet Gyrodyne.

By this means the Rotodyne is able to combine the take-off and landing performance of a twin-engine helicopter with a cruising speed of 170 m.p.h. Being able to operate from one city centre to another, some two hours of ground-handling time can be eliminated from the passenger's journey and, the manufacturers claim that for distances up to 400–500 miles, the total journey time by a 150 m.p.h. helicopter is less than that of a 500 m.p.h. airliner.

In comparison with present commercially-operated helicopters of the shaft-transmission type, the Rotodyne can offer a substantially higher disposable load, since a complex transmission gearbox is replaced by light stainless steel ducting; and the necessity for a torque reaction rotor is eliminated. On the Rotodyne, the weight is accounted for as follows: fixed airframe structure, 17·9 per cent.; power plant and rotor drive, 18·8 per cent.; the rotor itself, 13·9 per cent.; miscellaneous equipment, 10 per cent.; and disposable load, 39·4 per cent.—a remarkably high figure for a helicopter, for which it is more usually of the order of 28 per cent. Thus it is possible to carry a substantial payload over a useful range. According to the manufacturers' calculations, based on the Society of British Aircraft Constructors standard method of cost calculation, the Rotodyne should, in terms of direct operating cost per passenger mile, be somewhat more economical to operate than the Viscount airliner over sector distances of less than 150 miles.

One of the principal difficulties in helicopter operation hitherto has been the need for frequent replacement of rotor blades and other parts of the rotor assembly as their "life" is low under vibratory loading. On the Rotodyne, all parts of the rotor system are of steel and are designed to operate at a stress level well below the endurance limit, so that their fatigue life should be unlimited. The rotor head and blade roots are heavy machined steel forgings, and the blades themselves are of stainless steel.

The compressed air to each blade-tip jet unit is led through triple stainless steel ducts within each blade, the ducts being free to move axially relative to the blade shell to allow for differential expansion and for the flexing of the blades. Each Eland engine feeds one pair of opposing blades, the compressed air passing into and through ducts in the fixed wing, then by way of passages in the head to the blade roots.

The pylon carrying the rotor is attached to the wing, as are also the engine nacelles and the undercarriage. The latter is retractable and hydraulically operated. All the fuel is also carried in the wing, in bag tanks, and thus the whole lifting and propulsive system of the aircraft is independent of the fuselage. This gives flexibility to the fuselage design, enabling a large volumetric capacity to be provided, together with easy loading. In addition, changes of fuselage design to suit operational requirements are straightforward. This is already being done; the first Rotodyne has a fuselage section 8 ft. wide by 6 ft. high, whereas the second prototype is 8 ft. square in section.

On the first prototype, large clamshell doors at the rear of the fuselage permit the loading of bulky freight and vehicles; the Fairey company believe that the Rotodyne is particularly suitable for cross-Channel car ferrying.

Developments in silencing jet units are under investigation and the constructors believe that the noise of the Rotodyne at take-off and landing will be no greater than that made by conventional twin-rotor helicopters of much smaller size. Due to the high rate of climb, moreover, the noise will be heard for a much shorter time. In flight, the Rotodyne will be quieter than any conventional helicopter.

Cyclic and collective pitch control of the rotor are operated through Fairey hydraulic "booster" units. The wing and tail surfaces provided on the Rotodyne should give stability and control in forward flight comparable with that of a fixed-wing aircraft. With auto-stabilisation, slow descent into restricted areas in bad weather conditions should be straightforward.

The all-up weight at which the Rotodyne operates is determined by the ability to hover satisfactorily with one engine out of action, and on the prototype machine with Eland N.EL.3 engines, this has been settled at 33,000 lb. The structure, however, has been designed for a gross weight of 39,000 lb. so that when the 3,500 h.p. Eland N.EL.6 engines become available, full advantage can be taken of their greater power. At 39,000 lb., it is estimated, a payload of 10,000 lb. can be carried over 400 miles at speeds up to 170 m.p.h.

ATOMIC REVIEW

Reactor Systems

Reactor systems: Reducing reactor size by compact shielding—Fluidised solids as fuel or moderator—Liquid-metal coolant with heavy-water moderator—Stable heterogeneous reactor—Continuous removal of fission products—Problems of differential temperatures and pressures—Training courses: Isotopes and instruments—New programme at Harwell reactor school—Lecture on nuclear power development.

Compact Shielding

The main problem associated with the use of nuclear reactors for propelling aircraft and other means of transport is that of shielding. To protect crew and passengers from harmful radiation, a considerable bulk of shielding material, perhaps concrete, would be necessary, and this would, in the case of aircraft at least, represent a serious loss of space and carrying capacity. A means of minimising this disadvantage has been suggested by the firm, Stichting voor Fundamenteel Onderzoek der Materie, 6 Bijlhouwerstraat, Utrecht, the Netherlands. The invention is said to be of particular importance where reactors of small critical dimensions are concerned, as for example reactors using ordinary or heavy water as moderator, or reactors in which enriched uranium is employed.

The company propose that a considerable improvement can be achieved by use of a shield which substantially consists of bismuth or a bismuth compound and by providing means for removing the heat produced therein. The suitability of bismuth for this purpose lies in its very high absorption capacity for electromagnetic radiation, which amounts to about 5 per cent. of the total energy produced in a reactor. For example, the shielding efficiency factor for an electromagnetic radiation of 2 MeV is 2^{27} for a layer of metallic bismuth 40 cm. thick; a corresponding thickness of concrete would be 150 cm. and concrete protecting shields are in fact generally of the order of 150 to 300 cm. in thickness. Preferably metallic bismuth would be used since it combines maximum effectiveness with minimum volume.

The invention is of special advantage for those reactors in which bismuth or a bismuth compound is used as the reflector material. It has a low effective neutron capture cross-section —lower than 0·03 barn—and a high effective neutron scattering cross-section—9 barn. The purpose of a reflector is to prevent undue wastage of valuable neutrons; thus a material that does not absorb them but scatters or disperses them back to the reactor core is required; in practice reflectors are generally constructed of materials, such as graphite, which also have a moderating (neutron slowing) effect. If bismuth is used as the reflector it can in fact be combined with the protective shield to form an integral unit, both functions being performed by the same item. Thus the 40 cm. thick metallic bismuth shield previously mentioned would be equal to the neutron reflection efficiency of a graphite layer 40 cm. thick, plus a concrete layer of 150 cm.

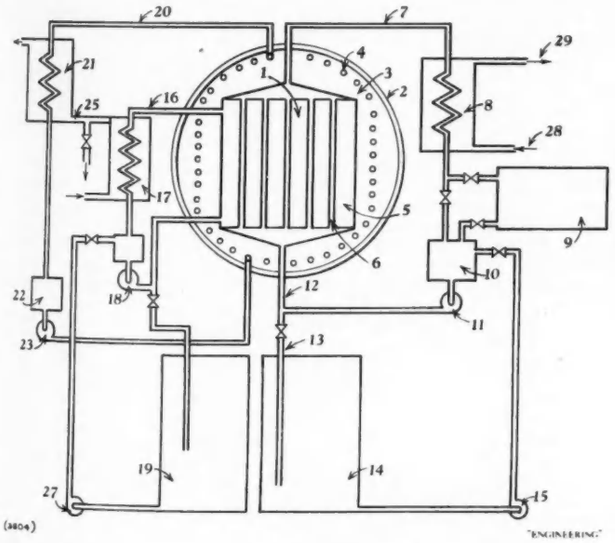
The use of metallic bismuth also simplifies the provision of means for heat removal. For instance, the shield may be constructed of profilated elements, which may be joined in such a way that channels are left between them through which coolant may be circulated. Alternatively, it is possible to fit pre-fabricated cooling coils in the space allotted to the shield and then cast the bismuth into place. The problem of heat removal can be quite serious in the case of a concrete shield with its low thermal conductivity, and local hot spots may develop resulting in undue stresses and even disintegration. Adequate cooling of a concrete shield can prove difficult in practice. Another advantage of a bismuth shield obtains for reactors in which the reactor coolant is contained in a pressure vessel as in gas-cooled or pressurised-water systems. In this case the protective shield can be constructed inside the pressure casing so giving an efficient and compact installation. However, it should be noted that access to the shield cooling system would then be impossible and care must be taken in the design to avoid choking of the coolant channels.

Fig. 1 shows a possible reactor based on these principles in which a liquid fuel suspension (uranium oxide in heavy water perhaps) and a liquid moderator (heavy water) are used. There are in effect three circulating systems, each supplying heat for power generation: fuel, moderator and shield coolant, though the shield cooling and moderator systems are to some extent combined. The core tube system (6) in which the fuel circulates and which is surrounded by moderator should be made of a material with low neutron absorption capacity and low heat conductivity, such as a thin beryllium-oxide wall coated on the outside with a loosely sintered beryllium-oxide layer. Operating temperatures may be roughly as follows: uranium oxide suspension leaving the core 300 deg. C.; moderator in core 50 deg. C.; and shield and reflector jacket 200 deg. C. To prevent heat transfer from jacket to moderator, the jacket should, like the core tube system, be coated with a heat-insulating material, such as loosely sintered beryllium oxide. (British Pat. Spec. 751,700.)

Fluidised Reactors

A reactor in which the fuel is in fluid form offers considerable advantages in respect of fuel processing and removal of fission products, heat transfer, heat distribution within the reactor core, maintenance and fuel-preparation. However, liquid or dissolved fuels are not always convenient and problems of corrosion, interaction and decomposition may be serious. A means of combining some of the advantages of both solid and liquid fuel systems is provided by a reactor scheme in which fuel and perhaps moderator too are in the form of finely divided solids, which are fluidised by means of a circulating gas or liquid. (See ENGINEERING, vol. 181, page 356, 1956, and vol. 180, page 499, 1955.) Several reactor designs based on this approach have been proposed by the Texaco Development Corporation, 135 East 42nd-street, New York 17, U.S.A., in a recent patent specification. One version is shown in Fig. 2.

The reactor comprises a reactor chamber of changing section in which the solids—possibly uranium oxide U_3O_8 or a plutonium compound, together with a moderator such as beryllium oxide or graphite—are fluidised by a gas or mixture of gases, which flow in a closed circuit. These may be air, helium, hydrogen or deuterium.



1. Reactor core
2. Pressure shell
3. Metallic bismuth reflector and shield
4. Shield cooling tubes
5. Moderator space
6. Fuel tube system
7. Pipe to heat exchanger
8. Heat exchanger (fuel)
9. Fuel purifier (fission product removal)
10. Collecting tank
11. Pump
12. Core entry pipe
13. Drain pipe
14. Reserve tank (fuel)
15. Pump
16. Moderator pipe
17. Heat exchanger (moderator)
18. Pump
19. Reserve tank (moderator)
20. Shield coolant pipe
21. Heat exchanger (shield coolant)
22. Pump cistern
23. Pump
25. Connecting pipe
27. Pump
28. Inlet pipe
29. Outlet pipe

Fig. 1 (left) Nuclear reactor scheme with shield and reflector combined and located inside the pressure shell. Bismuth or a bismuth compound is used as shielding material and the shield itself is cooled.

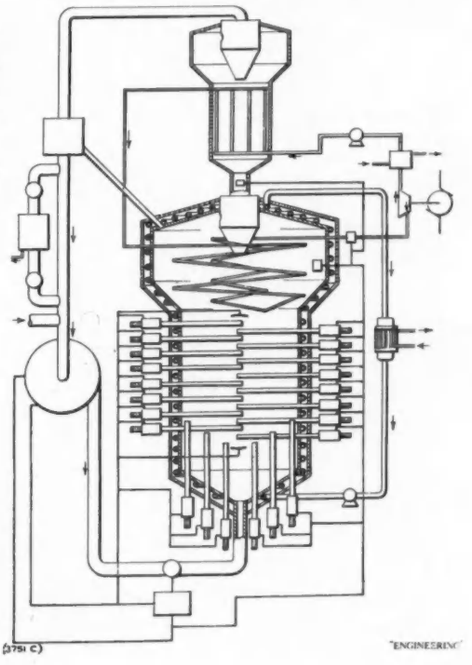


Fig. 2 (right) Reactor system in which fuel and moderator may be finely divided solids suspended in a fluidising gas. Alternatively, the fuel may be in gaseous form as may the moderator.

The gas itself might even be fissionable—uranium hexafluoride, for example—with a powdered solid moderator. Moreover, control can be assisted by using a "retarding" gas mixed with the others in adjustable proportions. The chamber is wider at the top to reduce the gas velocity, so permitting easier separation of the fluidised material. Into the chamber at both sides and bottom are inserted so-called "retarder" rods, of cadmium or boron, which are in effect control rods governed automatically by servo-mechanisms operated by temperature or radiation-measuring devices. Coolant coils leading directly to a turbine or to a heat exchanger are provided both in the walls of the reactor chamber and inside the wider section at the top of the chamber. A cyclone separator is fitted in the chamber roof and a second one above that; farther along the circuit leaving the top of the reactor is an ultrasonic or electrostatic precipitator. At this point the gas fluidising medium should be free from solids, which will have been returned by the separators and precipitator to the reactor chamber. An isotope separation device is fitted in parallel with the main pipeline so that gaseous isotopes produced may be extracted. A pump maintains the gas flow. In addition to the fuel, the fluidised solids may contain zirconium, magnesium or aluminium particles which have low neutron capture cross-sections but facilitate heat transfer. Sodium, potassium, bismuth, lead, water or diphenyl are among possible external coolants. Fig. 3 shows a modification of the system in which mechanical fluidisation is combined with the use of a gaseous fluidising medium; means are provided for cooling the rotating blades.

Control of reaction rates in this system is said to be easily effected since changes in pressure and gas composition can rapidly be made in addition to retarder adjustement. In a third arrangement, the retarders are disposed in accordance with the anticipated solids distribution throughout the reactor chamber. A further safety feature would be the provision of a retarder at the base of the chamber, so that on cessation of gas flow, the solids would collect about it under gravity and the reactor be shut down. Another advantage is that if hydrogen is used as the fluidising medium neutron capture will result in the formation of deuterium, which can be removed from the circuit to give a valuable by-product. (British Pat. Spec. 749,064).

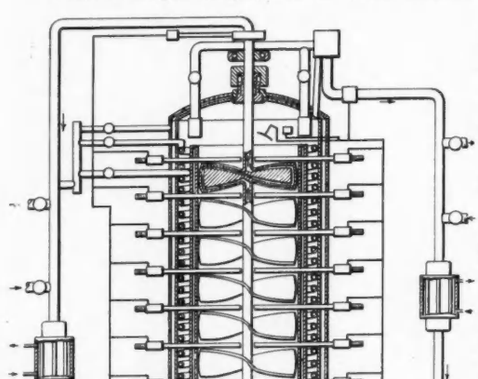


Fig. 3 Fluidised-solids reactor design, in which both mechanical and gaseous fluidisation are employed. The rotating blades have channels for cooling purposes.

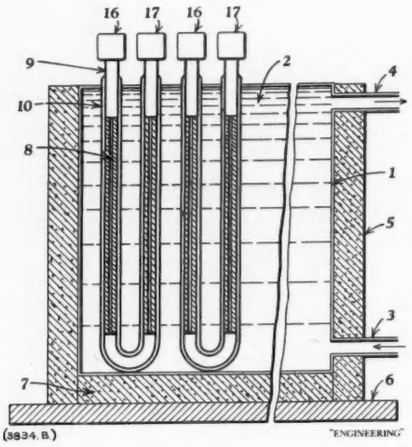


Fig. 4 If, in a reactor, water serves as both coolant and moderator, high temperatures can only be attained if it is pressurised. However, by using a liquid metal to extract most of the heat from the fuel elements, the moderating water can be kept at atmospheric pressure,

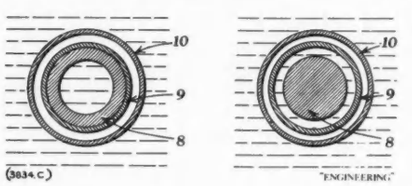


Fig. 5 Cross-section of fuel elements cooled by liquid metal with heavy water as moderator. On the left the coolant is carried inside a hollow fuel rod; on the right concentric cylinders contain first the metal coolant and second an insulating and protecting gas space.

Low-Pressure-Water Moderator

In power reactors heavy water is a particularly suitable moderator as it has such a low neutron absorption capacity that natural (non-enriched) uranium can be used as fuel. However, if high temperatures are to be achieved—as is necessary for high efficiency—the water must be pressurised, otherwise boiling will occur. This is often inconvenient and if boiling is allowed to take place, control is difficult. To avoid this dilemma the Allmanna Svenska Elektriska Aktiebolaget, of Vasteras, Sweden, have proposed an arrangement whereby heat is removed rapidly from the fuel by liquid metal while the heavy-water moderator is maintained below 100 deg. C. and at atmospheric pressure.

Fig. 4 shows such a reactor. The uranium or thorium fuel rods are formed in the shape of hollow pipes and cooled internally by liquid metal as shown on the left in Fig. 5. A liquid metal such as sodium should be chosen which does not attack uranium. The fuel rods (8) are contained in lightly fitted tubes (9) of a material like zirconium which does not absorb neutrons; outer concentric pipes (10) of zirconium or aluminium surround the fuel casing tubes leaving a gap of several millimetres. This can be evacuated or filled with a protecting gas, such as helium or carbon dioxide; thus little heat can be transmitted to the heavy water (2) contained in the graphite chamber (5 and 7). This chamber, which rests on a base (6), is lined with some material such as aluminium forming a vessel (1) for the heavy water. Pipes (3 and 4) connect the vessel with a heat exchanger, where the turbine working fluid is preheated.

Obviously various arrangements both of the piping round the fuel elements and the reactor itself are possible and the scheme illustrated makes use of a U-tube system—as distinct from headers top and bottom—with distributing (16) and collecting (17) pipes, so that the base of the vessel is left intact. On the right in Fig. 5 a cross-section is shown in which the uranium rod is solid with concentric annular cylinders containing first liquid metal and then the insulating gas. The principal disadvantage of this system seems to be the leakages and faults that might occur as the result of fuel-element distortion during operation, but steps can probably be taken to avoid this. (British Pat. Spec. 754,183).

Reactor Stability

If a chain reaction is to remain stable or non-explosive the total loss of neutrons must balance exactly the total number of neutrons produced by fission of the nuclear fuel. Some of course, are used to maintain the chain reaction, others to transmute fertile material (uranium 238 to plutonium 239, for example), while still others are captured by materials of construction or lost outside the reactor. As is well known, there is a minimum or critical core size for a reactor below which a chain reaction cannot be sustained and above which the reaction will diverge until an explosion occurs. In a homogeneous reactor in which fuel and moderator are intimately mixed as fluids, control can easily be effected by changing the volume of the core by means of valves. An invention due to members of the United Kingdom Atomic Energy Authority permits similar control of heterogeneous reactors in which fuel and moderator are separate, as when the fissile fuel is in the form of rods. Although the specification for this invention has only been published

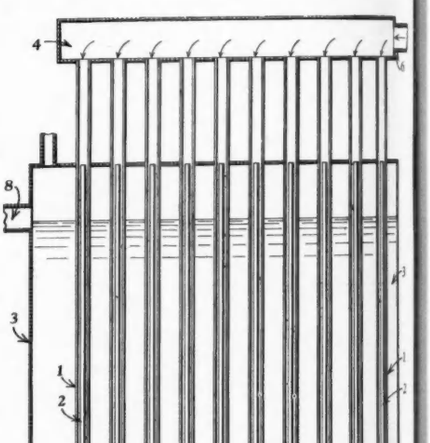


Fig. 6 In a heterogeneous water-moderated reactor stability can be achieved by changing the liquid level of the moderator. However, the fuel rods must remain immersed in coolant and a second liquid system with headers (4 and 5) is therefore necessary.

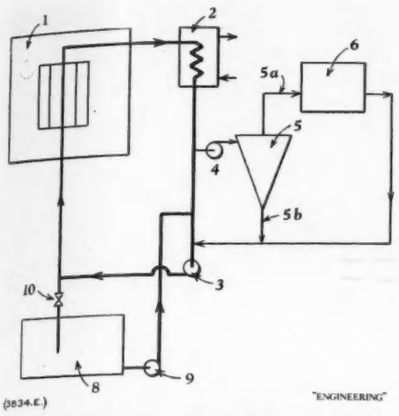


Fig. 7 By using as reactor fuel a particulate solid suspended in a carrier liquid and carefully controlling particle size, unwanted fission products can be removed, while valuable fissile materials formed from fertile elements by neutron capture may be retained.

this year, it was originally taken out in 1945. The use of neutron absorbing control rods has since become more common for achieving the same purpose, but nevertheless the invention is interesting in that it indicates an alternative approach.

In the proposed design water was a suitable moderator, and if some of this were drawn off from the solid fuel in order to control the chain reaction, part of the fule would remain uncooled as a result of the change in liquid level. However, in this invention it was proposed that the coolant and moderator—though perhaps the same material—should be separate. One form of the proposed reactor is shown in Fig. 6. Fuel rods (2) are contained in tubes (1) within the shell (3). The tubes are connected to headers (4 and 5) at the top and bottom, which are provided with an inlet (6) and an outlet (7); a similar inlet (8) and outlet (9) are joined to the reactor shell. Thus no matter what changes are made in the level of the moderating liquid in the reactor vessel, the cooling liquid remains in total contact with the fuel rods. (S. G. Bauer and R. E. Newell. British Pat. Spec. 753,130.)

Removing Fission Products

During a chain reaction in a nuclear fuel, various products are formed as the result of fission which are unfavourable to the reaction since they absorb the neutrons necessary for its continuation, and thus reduce the efficiency of fuel usage. A system has been devised by the company, Stichting voor Fundamenteel Onderzoek der Materie, to overcome this drawback, by which undesirable impurities are continuously removed from the nuclear fuel, but desirable fissile material such as plutonium 239 or uranium 233 formed from fertile material by neutron capture is retained.

According to the invention, the nuclear fuel is carried in the form of a stable suspension of solid fissile material in a carrier liquid, in which substantially all the suspended particles have a maximum diameter smaller than 15 μ. The fission products are then largely capable of leaving the fuel particles and are subsequently slowed down by and detained in the carrier liquid. Thus if part of the carrier liquid is separated from the suspension, purified by, for example, ion exchangers or adsorbers, or both, and then returned to the reactor vessel, the concentration of undesirable fission products can be maintained at a satisfactorily low level. In addition, particles may be removed from the liquid for removal of adsorbed impurities. However, those nuclei which are formed by neutron capture and subsequent beta emission like plutonium should not be allowed to leave the fuel particles. Therefore, it is preferable to use a fuel suspension in which substantially all the suspended particles have a minimum diameter greater than 0·01 μ. Suitable suspensions might be dispersions of oxides of natural or slightly enriched uranium in heavy water, and dispersions of enriched uranyl oxides in natural water or natural water enriched with heavy water. In these cases, the carrier liquid simultaneously acts as moderator. In order that separation of the suspension from the carrier be quick and efficient it is necessary to qualify the character of the particles once more. When a hydrocyclone thickener is used, separation is satisfactory only if the mean effective diameter of the suspended particles is equal to or greater than 1 μ. Thus particle size must lie in the range 0·01 μ to 15 μ and satisfy in addition this last condition.

Fig. 7 illustrates diagrammatically a suitable system for applying these principles. The suspension is circulated, with the aid of a pump (3), through the reactor (1) and a heat exchanger (2). Part of the suspension is pumped, by a second pump (4), through a hydrocyclone thickener (5), which is so adjusted that the fraction issuing from the overflow (5*a*) consists of carrier liquid without particles, while a slightly thickened suspension is obtained from the apex (5*b*). The liquid freed of suspension is rid of foreign matter in a purification plant (6), from which it is returned to the main circuit together with the slightly thickened suspension. The installation is also provided with a reserve tank (8), into which the suspension may be rapidly drained in cases of emergency by stopping pump (3) and opening valve (10). The suspension may be returned to the circuit by means of a pump (9). (British Pat. Spec. 753,399.)

Pressures and Partitions

In some of the schemes we have described so far, where fluids or fluid suspensions serve as fuel and moderator, it has been necessary to divide the coolant from the moderator by enclosing the fuel elements in tubes or by use of partitions. This presents problems of pressure difference where one of the fluids is compressed and of insulation where they are at different temperatures. For instance, if light or heavy water is to be prevented from boiling, the practical temperature limit is about 300 deg. C., in which case an excess pressure of some 80 atmospheres is required. To overcome these difficulties Stichting voor Fundamenteel Onderzoek der Materie have suggested two possible approaches.

One proposal is based on the consideration that it is impossible to install pressure-proof pipes or vessels inside a reactor, since the thick pipe walls necessary would absorb neutrons to such an extent that a chain reaction could only be maintained by using a highly enriched nuclear fuel. This would be extremely wasteful. Instead, therefore, the entire reactor could be contained in a pressure vessel, including part of the reflector; pressure-proof conduits carrying the various circulating fluids would be connected to this casing. An essential feature of such a system would be means of keeping the pressure difference between the two fluids below a certain value to prevent distortion of the non-pressure-proof internal dividing walls. The principal disadvantage of this design would be difficulty of access, thus impeding maintenance.

To control the reactor, part of the reflector (made of beryllium oxide or bismuth) is placed outside the pressure casing and shifted to vary the number of neutrons scattered back to the reactor core. Alternatively, some neutron absorbing material could be placed between the reflector and the reactor vessel. If heavy water is used as moderator, precision control may be effected automatically since the moderating properties of heavy water decrease with increasing temperature. (British Pat. Spec. 751,429.)

Thus, in the course of this article we have seen that reactor control can be achieved by adjustments (automatic or otherwise) to the moderator (which slows down the neutrons to a suitable speed to cause fission) to the reflector (which scatters neutrons, that would otherwise be lost, back to the reactor), or to control rods (which absorb neutrons so reducing the rate of reaction). These three items would be made of materials with different neutron cross-sections, though there is of course some overlapping.

The second approach suggested by the Dutch company concerns the problem of thermal insulation when the contained fluids are at widely different temperatures, as in the case of a coolant in contact with the fuel and a separate moderator. Essentially, the partition walls must be of low neutron absorbing capacity so that a thick insulation is not permissible. The suggested partition wall comprises a thin layer of tightly sintered beryllium oxide coated on the side facing the moderator with a layer of loosely sintered beryllium oxide. The cavities in this material will become filled with heavy water and good heat insulation will thereby be obtained. It has been found that if the loose layer is 1 cm. thick, the quantity of heat carried away by the moderator at a temperature drop of 250 deg. C. across the wall is only 7 per cent. of the heat produced in the reactor. However, 5 per cent. of this is generated in the moderator itself; thus only 2 per cent. is transmitted by conduction through the wall. (British Pat. Spec. 752,152.)

Instruction Courses

Isotope Developments Limited, Beenham Grange, Aldermaston Wharf, near Reading, Berks., are running comprehensive courses, both theoretical and practical, on the industrial and research applications of atomic energy. They are primarily intended for training home and overseas sales representatives and sales engineers. Among the subjects treated are industrial equipment, counting techniques, reactor instrumentation and isotope handling, and visits are arranged to various firms and establishments.

The University of London, Senate House, Malet-street, London, W.C.1, are arranging a university extension course on "Technology and Industry," to be held on Fridays at 6.30 p.m. beginning October 12, 1956, at the London School of Hygiene and Tropical Medicine, Keppel-street, London, W.C.1. Among the topics to be covered is "The Development of Nuclear Power," which will be discussed on December 7, by Mr. R. V. Moore, G.C., B.Sc., M.I.E.E., A.M.I.Mech.E., Assistant Director, Civil Reactor Department, United Kingdom Atomic Energy Authority. The fee for 10 lectures is 15*s*. Single tickets cost 2*s*. Inquiries should be made to the University of London Cashier at the Senate House.

When the Harwell Reactor School started its latest course on September 10, it was housed in a new building which can accommodate more students than was possible hitherto. The number of courses has also been increased to meet demands from industry, the universities and technical colleges. The standard three-months' course includes about 150 lectures and a large number of practical experiments. In addition, for the first time, will be offered concurrently with the three-months' course, one of six weeks duration, which is in fact the first six weeks of the standard course and mainly concerned with the fundamental physical and engineering principles of reactor design. It is expected to be of interest mainly to lecturers from universities and technical colleges and to the staffs of firms working on ancillary aspects of the Nuclear Power Programme. Courses 9 and 10, of 6 and 14 weeks duration respectively, commence on February 4, 1957; course 11 (6 weeks) on June 3, 1957, and courses 12 and 13 (6 and 14 weeks) on September 16, 1957.

(*Some further comments on reactor design, including a description of a new scheme to be adopted in the United States based on a sodium-deuterium system, will appear in a subsequent Atomic Review.*)

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The consulting civil engineers for the Carrington power stations described in our issue of August 31, page 274, were C. S. Allott & Son, North Parade, St. Mary's Parsonage, Manchester, 3.

BRITISH AIRCRAFT TO-DAY

2—POWER UNITS AND BOOSTERS

Last week we described airliner developments as seen at the Society of British Aircraft Constructors' display at Farnborough. This week is devoted to power plants and rocket booster units.

As last year, the principal interest in this year's display and exhibition by the Society of British Aircraft Constructors at Farnborough lay in the engines. The 13,000 lb. thrust Rolls-Royce Conway by-pass turbojet which made its debut last year has fulfilled the industry's hopes in penetrating to the American market, and will be fitted in the Douglas DC8 airliners destined for Trans Canada Airlines and the Boeing 707's for Luft Hansa and Air India International. We understand from Rolls-Royce that, since Trans Canada set a precedent by specifying Conways, no subsequent order for either of the American jetliners has called for American turb. jets. The Conway was not flying but could be seen in the static exhibition. The other outstanding débutante of 1955, the 15,000 lb. thrust de Havilland Gyron, again appeared in the flying display in its Short and Harland Sperrin flying test-bed, which this year has two Gyrons installed in the lower nacelles. In the static exhibition, the Gyron's younger brother, the Gyron Junior, was on view, but no details of its performance or construction have been released, other than that it is intended to power aircraft operating at high supersonic speed, in conjunction with liquid-propellant rocket engines. It has, therefore, been designed for a low frontal area and a low specific weight. The design of the axial compressor, cylindrical combustion chamber and turbine assembly is common to all members of the Gyron family.

This year, two important new propeller turbines have appeared in public for the first time—the Rolls-Royce Tyne and the Bristol Orion.

TYNE PROPELLER TURBINE

Rolls-Royce Limited, Derby, demonstrated their 4,470 e.h.p. Tyne propeller turbine installed in the nose of a Lincoln flying test-bed; and it was an impressive sight to see the Lincoln climbing on the Tyne alone, with all its normal airscrews feathered. This engine, it may be recalled, is to power the Vickers Vanguard airliner which British European Airways have ordered for delivery in 1960, and is also offered as an alternative power plant for the Lockheed Electra airliner.

The Tyne, intended for a speedier generation of aircraft than that at present in service, combines high specific thrust with good economy. It is a two-shaft engine with a design pressure ratio of 12 to 1, in which the low and high pressures are independently driven by the low and high pressure turbines, the low-pressure shaft running inside the hollow bore of the high pressure shaft. The propeller is coupled to the low-pressure shaft through a compound epicyclic reduction gear (0·062 to 1), the mounting of which is designed to damp out vibration. The engine is controlled by a single lever coupled with the propeller control. The de-icing system for the propeller, spinner and air-intake leading edge is based on experience with the Dart engine, which has proved to be very satisfactory in this respect.

The principal particulars of the engine are as follows: for take-off in standard atmospheric conditions, the Tyne develops 4,020 s.h.p. plus 1,175 lb. jet thrust—giving an equivalent power of 4,470 e.h.p. For cruising the total equivalent power is 2,470 e.h.p., with a specific fuel consumption of 0·414 lb. per e.h.p. per hour. The net dry weight of the engine is 1,880 lb., giving a specific weight of 0·42 lb. per e.h.p. The overall dimensions are: length to cone fitting, 97·10 in.; height, 40·5 in.; and width, 37·4 in.

Fig. 6 The Orion "supercharged" propeller turbine on its test-bed. Bristol Aero-Engines Limited.

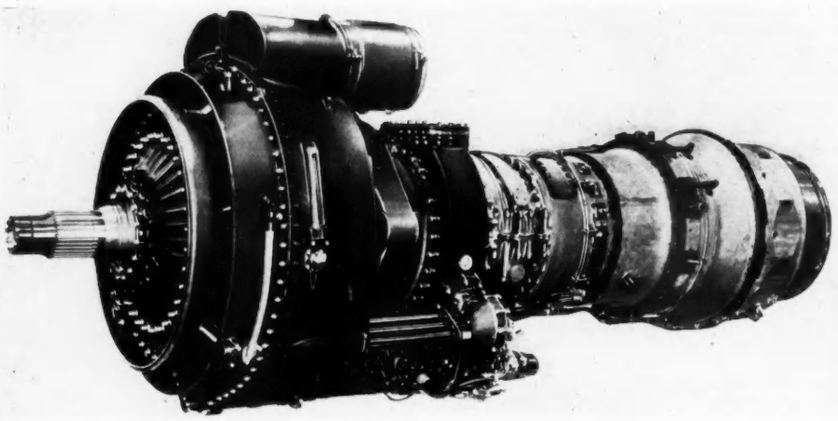

Fig. 4 The Tyne propeller turbine. Rolls-Royce Limited.

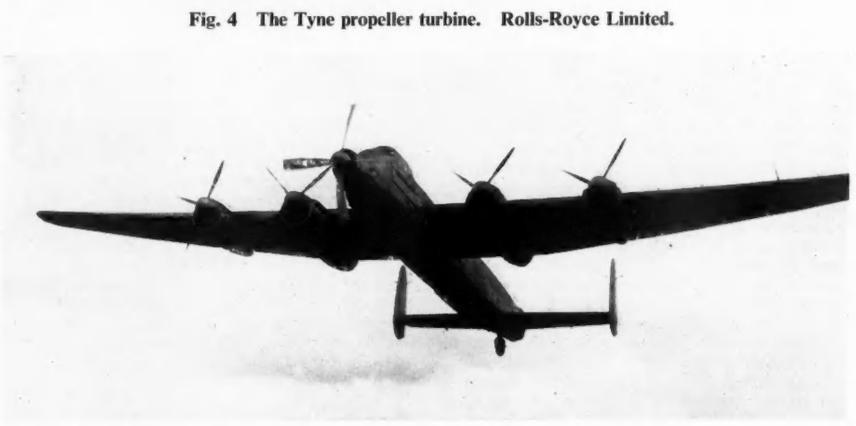

Fig. 5 The Lincoln flying test-bed is seen here propelled solely by the Tyne propeller turbine mounted in the nose.

ORION PROPELLER TURBINE

Another two-shaft propeller turbine based on a different design philosophy, and described by its manufacturers, Bristol Aero-Engines Limited, as a supercharged propeller turbine, is the Orion engine which was demonstrated in the port outer position on a Britannia flying test-bed. Designed specifically for transport operation, the Orion, by limiting the torque at lower altitudes, maintains a constant take-off power of 4,400 s.h.p. from sea level to 20,000 ft.; thus an aircraft powered by Orion engines can always call upon full take-off power whatever the altitude of the airfield or the prevailing temperature—a characteristic which will greatly simplify flight planning. Four Orions will power the Bristol 187 transatlantic airliner.

The Orion comprises a five-stage high-pressure compressor, combustion system and single-stage high-pressure turbine, this high-pressure system being supercharged by a seven-stage low-pressure compressor driven by a three-stage low-pressure turbine from the exhaust of the high-pressure system. The low-pressure system is geared to the propeller, and is not mechanically connected to the high-pressure system. The engine is comparable in size and weight to the Proteus, and in fact utilises the Proteus propeller and epicyclic reduction gearbox. The combustion system is of the "cannular" type with ten flame tubes enclosed between inner and outer annular casing walls. Each flame tube has a fuel injector at its upper end.

The Orion has an overall length of 112·3 in. and a diameter of 41·75 in.; the dry weight, including oil tank, oil coolers and suspension units, is 3,150 lb. Although proved performance figures are not yet available, the designers' estimates have been surpassed on test and it can be said that an ensuing specific fuel consumption of less than 0·4 lb. per e.h.p. per hour has been achieved.

PROTEUS 755 PROPELLER TURBINE

Also mounted in the Britannia flying test-bed, in the starboard outer nacelle, is the Bristol

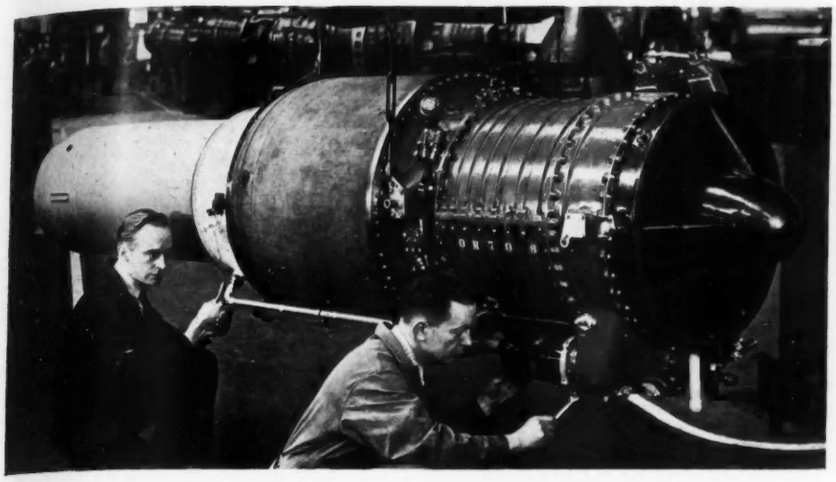

Fig. 7 The Orpheus light-weight turbojet. Bristol Aero-Engines Limited.

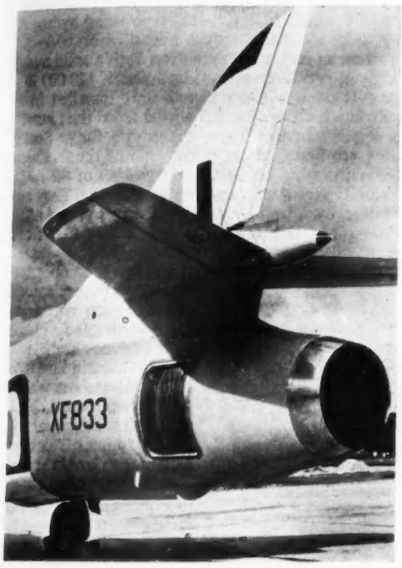

Fig. 8 Thrust reverser unit fitted in a Hawker Hunter aircraft. Rolls-Royce Limited.

Proteus 755 turbo-propeller, of the free power turbine type, which powers the 300 series of Britannias—a more powerful development of the 3,900 e.h.p. Proteus 705 engine on the earlier Britannia.

The principal differences between the Proteus 755, which develops 4,120 e.h.p., and the earlier engine, lie in the power turbine, which has been re-matched to the compressor to give a lower specific fuel consumption for cruising; in a weight reduction resulting from a wider use of magnesium castings; and in the accessory drive. The mechanical accessory drives can now be replaced by electrical drives supplied by a 47 kVA alternator driven from the gearbox.

The leading particulars of the Proteus 755 are as follows: overall length, 113·25 in.; diameter, 40·1 in.; reduction gear ratio, 0·09 to 1; dry weight, 2,850 lb.; maximum take-off power, 4,120 e.h.p., with a corresponding specific fuel consumption of 0·6 lb. per e.h.p. per hour; maximum continuous power (sea level) 3,790 e.h.p. with a corresponding specific fuel consumption of 0·595 lb. per e.h.p. per hour.

ORPHEUS TURBOJET

Seen for the first time last year, the Bristol Orpheus light-weight turbojet was again on view in the static exhibition and flying in the Folland Gnat. This engine is also on order for the Fiat G.91 and Aerfer Ariete of Italy, the French Dassault Etendard 6 and Breguet Taon, the Yugoslav Icarus B.12, the Spanish Hispano HA300 and the Japanese Fuji FITI trainer aircraft. Some 20 engines have so far been built and delivered to the Folland and Fiat companies.

The engine is 90·25 in. long overall and has a diameter of 32·4 in. Simple in construction, and of well-tried materials, the Orpheus has an axial compressor and an annular combustion chamber with separate flame tubes.

Over 100 hours flight testing and more than 5,000 hours bench testing have been completed since the Orpheus first ran some 19 months ago, and the engine has now been type-tested to 4,050 lb. thrust.

REVERSE THRUST

Another important Rolls-Royce development was displayed in a Hunter aircraft equipped with a reversed-thrust mechanism for reducing the landing speed—the first occasion on which a British reversed-thrust device has been demonstrated. (The French SNECMA thrust reversal system, it may be recalled, was demonstrated in flight at the Paris Salon in 1953). In the Hunter installation the Rolls-Royce thrust reversal system, of which few details are available, operates by blanking off the normal jet exhaust orifice by means of "eyelid" shutters, and deflecting the jet exhaust through aerofoil vanes on the side of the fuselage.

GAZELLE SHAFT TURBINE

In the static exhibition, the Gazelle free turbine for helicopter shaft transmission was on view on the stand of D. Napier and Son, Limited, Acton, London, W.3. Originally designed for a power of 1,260 s.h.p., the Gazelle surpassed this power on the initial calibration run, and achieved a lower fuel consumption than had been predicted; it is now being developed up to 1,800 s.h.p. The Gazelle has been selected for the Bristol 192 twin-rotor naval helicopter and for the S.58 Westland Wessex single-rotor machine. The initial 1,260 h.p. version has a specific fuel consumption, at sea-level maximum continuous power, of 0·773 lb. per s.h.p. per hour, and has a net dry weight of 780 lb.

The Gazelle comprises a turbo-compressor unit exhausting to a single-stage free-power turbine, which is mounted co-axially with, but mechanically independent of, the turbo-compressor unit. It has been designed for mounting in horizontal, vertical or intermediate positions, as required, with either right or left-hand rotation of the output shaft.

The turbo-compressor unit consists of an axial-flow compressor which delivers air to the combustion chamber system, where fuel is burned continuously. The products of combustion are delivered to a two-stage axial-flow turbine which drives the compressor through a gear-type coupling. The combined rotor assembly of the turbo-compressor unit is mounted on three bearings.

The combustion chamber system comprises an outer casing containing six separate flame tubes, each of which has an upstream injection burner which can be independently removed to facilitate servicing. The outer casing forms a structural member of the engine and carries the turbine and reduction gear units.

The final drive is taken through an epicyclic reduction gear from the power turbine shaft. A Napier hydraulic torquemeter is incorporated in the reduction gear. The exhaust gases are discharged to atmosphere through a bifurcated jet pipe, and the reduction gearbox is placed within the bifurcation to minimise the length of the engine. Each bifurcation ends in two circular section ducts, allowing the jet pipes to be attached by clips to facilitate changing the engine unit. The engine width is slightly reduced by the splitting of each bifurcation.

Air is bled from the compressor to cool the turbine rotor discs, to supply air to the turbine and compressor balance pistons, to cool the compressor delivery end bearing and turbine bearings, and to supply hot air to the inlet guide vanes of the compressor to give protection against icing. Cooling air for the oil cooling system is provided by a centrifugal fan, which also supplies additional air for cooling and ventilating the engine bays. Provision is made for hot oil anti-icing of the compressor intake.

All the engine accessories are disposed around the compressor on the radial air intake and are driven, through spur gearing, by the intake end of the compressor shaft. Gear-type scavenge pumps are fitted for the compressor-end turbine bearings, and a pressure pump to supply the reduction gearbox end bearings; there is a separate pump for the torquemeter. The remaining engine accessories are the fuel pump, oil cooler fan, centrifugal breather and r.p.m. generator. Provision can also be made for driving a limited number of aircraft accessories.

An electrical starter is fitted adjacent to the compressor, and its drive-shaft passes through a

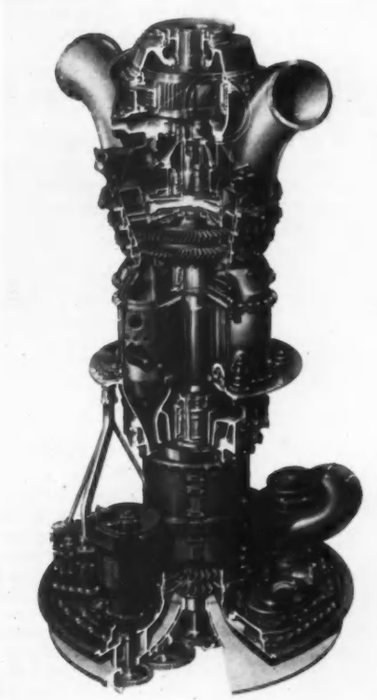

Fig. 9 Cut-away view of the Gazelle free-turbine helicopter engine. D. Napier and Sons Limited.

Fig. 10 The high-test peroxide tank for the Napier tip-thrust units on the Skeeter helicopter. Saunders-Roe Limited.

spat in the compressor intake to couple up, via gearing, to the compressor shaft. Alternative types of starter can be used.

Control of the turbo-compressor unit is effected by a single lever operating a Napier fuel metering unit, which automatically compensates for variations in flight conditions and incorporates a turbine-inlet temperature control and a maximum torque limitation. The free-turbine speed is controlled by rotor r.p.m., a safeguard being fitted to prevent over-speeding in the case of a transmission failure.

In multi-engined installations, in the event of failure of any one engine, automatic compensation increases the power from the other engine, and the fuel of the failed engine is automatically dumped.

The engine is mounted on pads situated on the main support plate between the compressor and the combustion chambers. The cut-away view of the engine (Fig. 9) shows an external tooth-type member fitted on the output end of the reduction gear casing for transmitting the torque reaction to the aircraft frame. Other means of transferring this torque have been designed to suit particular installations.

SCORPION ROCKET ENGINE

Examples of rocket populsion were shown by D. Napier and Son Limited, Luton, who demonstrated in action, for the first time, their Scorpion liquid-fuel rocket, two of which were mounted in the belly of a Canberra flying test-bed. Little information is available on the Scorpion, other than that it is intended for a piloted interceptor, and therefore is controllable in thrust and can be relighted in flight. Another rocket power plant designed for a piloted interceptor, on view in the static exhibition, was the Screamer of Armstrong Siddeley Motors Limited, Coventry, described in the August 31 issue of ENGINEERING.

NAPIER ROCKETS BOOST SKEETER HELICOPTER

Among the helicopters, the only new development seen at Farnborough this year was the Skeeter 5 helicopter demonstrated by Saunders-Roe, Limited, Eastleigh, with monofuel booster rockets fitted to the blade tips to give enhanced take-off performance for "abnormal" conditions such as when the helicopter has to operate heavily loaded, in tropical jungle country. The performance of the rocket units is independent of ambient conditions. The installation is the result of close collaboration between Saunders-Roe and D. Napier and Son, Limited, Luton, who have provided the tip-thrust units.

These units operate on high-test peroxide, which is stored in a rotating hemispherical tank (Fig. 10) mounted above the rotor head, and is pumped along the blades to the tip units by centrifugal action. Each unit consists of a catalytic steam generator, in which the liquid H.T.P. is decomposed into steam and oxygen, a curved exhaust chamber and a de Laval nozzle (Fig. 11) through which the steam is ejected at high velocity to provide the thrust reaction. No additional torque is imposed on the Skeeter's existing transmission system. The rotor speed is not increased, the power being absorbed in greater lift on the rotor blades.

By means of tip thrust, the sea-level vertical rate of climb of a normally-loaded Skeeter can be increased from 230 ft. to 1,400 ft.per minute, and the hovering ceiling from 1,100 ft. to 8,500 ft. The top speed can be increased from 88 knots to 100 knots, and the minimum rate of descent, with the normal piston engine out of action, is decreased from 1,300 ft. to 650 ft. per minute.

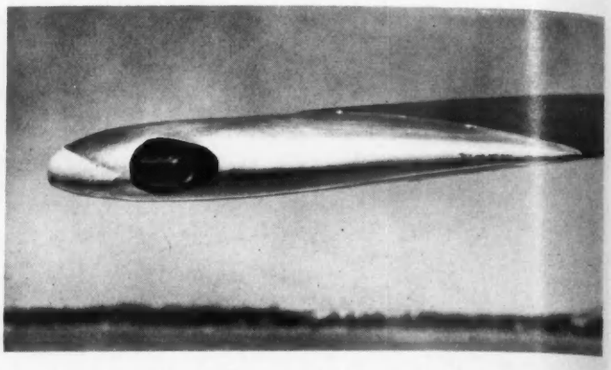

Fig. 11 The nozzle of the Napier tip-thrust unit at the rotor-blade tip of the Skeeter helicopter. Saunders-Roe Limited.

SUPER SPRITE BOOSTED VALIANT

Of the three V bombers appearing in the display —the Vickers Valiant, the Avro Vulcan and the Handley Page Victor—the first-named has now been in squadron service for over a year; the version demonstrated at Farnborough by Vickers-Armstrongs (Aircraft) Limited, Weybridge, is the second prototype Valiant equipped with two de Havilland Super Sprite rocket engines for assisting the take-off and initial climb, enabling the aircraft to operate at full take-off weight from relatively short runways, or from high altitude airfields or in high temperature conditions. It is shown in Fig. 12.

The Super Sprite rocket engine, which is of the bi-propellant liquid-fuel type using hydrogen peroxide as oxidant and kerosine or wide-cut gasoline as fuel, in conjunction with a solid metal catalyst, produces a total impulse of 120,000 lb.-sec. It is a self-contained unit installed in a nacelle which can be jettisoned from the aircraft in flight. In the Valiant, the two Super Sprite units are installed on either side of the fuselage, under the wing between the cowlings of the main Rolls-Royce Avon engines (Fig. 13). They are secured by a bomb-release mechanism, and after jettisoning, the wing surface is left free from obstruction.

After the release mechanism has been operated and the nacelle drops away, a static line releases a small drogue parachute to steady the initial motor of the nacelle, and a second static line triggers a release gun which, after a two-second delay, fires and releases an auxiliary drogue. This then causes the main parachute to be pulled out of its housing, two small auxiliary parachutes ensuring that its shroud lines are carried clear of the nacelle. As the canopy opens fully, doors in the base of the nacelle are opened automatically allowing a self-inflating rubber bag to expand in order to absorb the landing impact.

Fig. 12

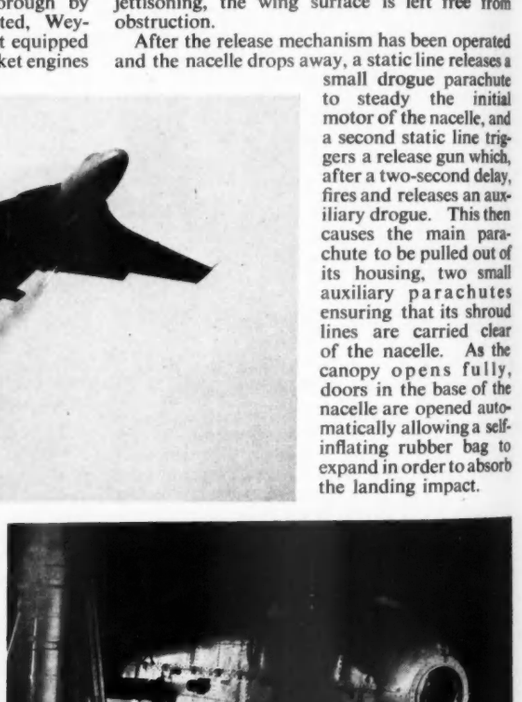

Fig. 13

Figs. 12 and 13. The Valiant boosted by Super Sprites for improved take-off. Vickers-Armstrongs (Aircraft) Limited.

Direct-current arc welding set with rectifier.

DIRECT-CURRENT ARC WELDING SET

High Efficiency—Balanced Load

To increase the efficiency of direct-current arc welding sets, the load provided by which may lead to problems on works substations and feeders, Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, 17, have produced the rectifier equipment which is shown in the accompanying illustration. This has an overall efficiency at full load of 71 per cent. and no load losses of 500 watts, compared with 46 per cent. and 3 kW for the more usual motor-generator set. It therefore compares favourably with the single operator alternating current welding set, which although its efficiency is high, has a low power factor and gives rise to an unbalanced load. In addition, the new set has a high initial surge which is particularly helpful with small gauge low hydrogen and alloy steel electrodes when striking the arc is difficult. The open circuit recovery voltage at the instant of breaking a short-circuit is from 15 to 20 per cent. greater than that of a motor-generator set.

STEPLESS CURRENT ADJUSTMENT

Stepless adjustment of the welding current of the standard set can be varied between 100 and 450 amperes by a wire-wound potentiometer. This controls the direct-current in a transductor circuit, connection from which is made by cable to the operator's position, 20 feet away. The voltage in this control circuit is about 25 volts. The range can be changed to 30 to 300 amperes by altering the transductor connections.

The only moving part which requires servicing is the fan, which draws in air at the top of the sets and expels it through the bottom louvres, thus minimising dust-deposition inside the set. The welding and earth-return leads are fitted with 450 ampere insulated sockets into which shrouded plugs can be inserted. These sockets, which are situated on the front panel are angled, as shown in the illustration, to prevent strain on the cables. The set provides a three-phase balanced load from the mains at an average power factor of 0·7 from one quarter to full load. The supply to the main transformer can be isolated by a three-pole rotary switch.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

CANTERBURY
"The Nightstor Heater," by R. Fielding. Kent Branch. County Hotel, Canterbury. Thurs., Sept. 20, 8 p.m.

OXFORD
"The Control of Automation," by L. Meeks. Oxford, Reading and District Branch. Regents Park College, Pusey-street, Oxford. Sat., Sept. 22, 6.30 p.m.

SOUTHAMPTON
"Some Problems in Sound Production," by F. H. Brittain. Southampton Branch. Polygon Hotel, Southampton. Thurs., Sept. 20, 8 p.m.

British Colour Council

LONDON
Silver Jubilee Celebrations, Mon., Sept. 24 to Wed., Sept. 26. British Colour Council, 13 Portman-square, W.1. Reception of members and delegates, Mon., Sept. 24, 6.30 p.m. "Colour through History," by R. J. Smith, Tues., Sept. 25, 10.30 a.m., and, at 2.45 p.m., "Colour over the Counter," by a panel of speakers. "Colour in Fashion," by J. Cavanagh, Wed., Sept. 26, 10.30 a.m., and, at 2.30 p.m., a Questions Session on "Colour Appeal."

British Institution of Radio Engineers

LONDON
"Some Aspects of Transistor Progress," by Dr. H. W. Loeb. London Section. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., Sept. 26, 6.30 p.m.

Building Centre

LONDON
Films: "Engineering in Wood" and "How to Finish Douglas Fir Plywood." Wed., Sept. 19, 12.45 p.m.

Illuminating Engineering Society

BIRMINGHAM
Chairman's Address, by V. A. Heydon. Birmingham Centre. Regent House, St. Phillip's-place, Colmore-row, Birmingham. Fri., Sept. 28, 6 p.m.

BRISTOL
"Lighting for Enjoyment," by T. O. Freeth. Bath and Bristol Centre. Royal Hotel, Bristol. Fri., Sept. 28, 7 p.m.

LEICESTER
Various short papers on "Interesting Lighting Jobs," by Centre Members. Leicester Centre. East Midlands Electricity Board's Offices, Charles-street, Leicester. Mon., Sept. 24, 6 p.m.

Incorporated Plant Engineers

BLACKBURN
"Maintenance of High Efficiencies on Economic Boilers," by I. S. Groundwater. Blackburn Branch. Golden Lion Hotel, Blackburn. Thurs., Sept. 20, 7.30 p.m.

CARDIFF
Films on "Lubrication." South Wales Branch. South Wales Institute of Engineers, Park-place, Cardiff. Fri., Sept. 28, 7.15 p.m.

LEEDS
"Radiography in Industry," by E. L. Grimwade. West and East Yorkshire Branch. The University, Leeds. Mon., Sept. 24, 7.30 p.m.

ROCHESTER
"Corrosion of Iron and Steel and Remedial Measures," by F. S. Bricknell. Kent Branch. King's Head Hotel, High-street, Rochester. Wed., Sept. 19, 7 p.m.

SHEFFIELD
Discussion on a civil engineering project. Sheffield Branch. Grand Hotel, Sheffield. Thurs., Sept. 27, 7.30 p.m.

Institute of Petroleum

LONDON
"Diesel Combustion Study by Infra-Red Emission Spectroscopy," by Dr. W. T. Lyn. Wed., Sept. 19, 5.30 p.m.*

Institution of Civil Engineers

LONDON
"The Problem of Liquid and Gaseous Effluent Disposal at Windscale," by F. R. Farmer. Public Health Division. Tues., Sept. 25, 5.30 p.m.*

Institution of Heating and Ventilating Engineers

BIRMINGHAM
"Electric Floor Heating," by T. F. Cadman. Birmingham Branch. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham. Tues., Sept. 25, 6.30 p.m.

GLASGOW
"Principles for the Selection of Mechanical Stokers for Boiler Plant," by E. J. MacDonald. Scottish Branch. Scottish Building Centre, 425 Sauchiehall-street, Glasgow, C.2. Tues., Sept. 25, 7 p.m.

MANCHESTER
"Intermittent Heating in Buildings," by E. Harrison. Manchester Branch. Engineers' Club, Albert-square, Manchester. Fri., Sept. 21, 6.30 p.m.

Institution of Locomotive Engineers

LONDON
Presidential Address by J. F. B. Vidal. Institution of Mechanical Engineers, 1 Birdcage-walk, St James's Park, S.W.1. Wed., Sept. 26, 5.30 p.m.*

Institution of Mechanical Engineers

BARROW-IN-FURNESS
"Water Ring Self-Priming Pumps," by E. Crewdson. North Western Branch. Central College of Further Education, Abbey-road, Barrow-in-Furness. Fri., Sept. 28, 7.30 p.m.

BRISTOL
Graham Clark Lecture on "The Engineer's Contribution to the Conservation of Natural Resources," by Sir Harold Hartley. Western Branch. University Engineering Laboratories, University-walk, Bristol. Tues., Sept. 18, 7 p.m.

FARNBOROUGH
"A Standard Gas Turbine to Burn a Variety of Fuels," by G. B. R. Feilden, J. D. R. Thorne and M. J. Kemper. Southern Branch. Royal Aircraft Establishment Technical College, Farnborough, Hants. Thurs., Sept. 20, 7.30 p.m.

HUDDERSFIELD
"The Influence of Some Design Factors on the Characteristics of Ball Bearings and Roller Bearings at High Speeds," by A. Fogg and J. S. Webber. Yorkshire Branch. Technical College, Huddersfield. Wed., Sept. 26, 7 p.m. (Preceded by a visit to W. C. Holmes & Co. Ltd., and Holset Engineering Co. Ltd., commencing at 2.30 p.m.)

MANCHESTER
"Mechanical Handling," by F. T. Dean. North Western Industrial Administration and Engineering Production Group. Engineers' Club, Albert-square, Manchester. Thurs., Sept. 20, 6.45 p.m.

Institution of Works Managers

GLASGOW
Annual General Meeting and Film Evening. Glasgow Branch. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Mon., Sept. 17, 7.30 p.m.

HULL
Open Discussion Meeting. Hull Branch. Royal Station Hotel, Hull. Wed., Sept. 26, 7.45 p.m.

LIVERPOOL
Annual General Meeting. Merseyside Branch. Adelphi Hotel, Liverpool. Tues., Sept. 18, 6.30 p.m.

Society of Instrument Technology

LONDON
"Accurate Calibration of Flowmeters," by Dr. E. A. Spencer and A. T. J. Hayward. Manson House, 26 Portland-place, W.1. Tues., Sept. 25, 6 p.m.

CHESTER
"A Nuclear Power Station and Its Instrumentation," by K. R. Sandiford. Chester Section. 5 King's Buildings, King-street, Chester. Wed., Sept. 26, 7 p.m.

GLASGOW
"Electro Simulators for Servo Mechanisms," by P. L. V. Pomella. Scottish Section. Royal Technical College, George-street, Glasgow. Fri., Sept. 28, 7.15 p.m.

Television Society

LONDON
"Receiver Considerations," by P. S. Carnt. Third of a series of five lectures. Assembly Hall, Institute of Education, Malet-street, W.C.2. Mon., Sept. 17, 7 p.m. (Fees for course: 10s. to members and £1 for non-members.)

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

* An asterisk is placed where it is understood that tea is available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Colour Council, 13 Portman-square, London, W.1. (WELbeck 4185.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Building Centre, 26 Store-street, London, W.C.1. (MUSeum 5400.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of Petroleum, Manson House, 26 Portland-place, London, W.1. (LANgham 2250.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Locomotive Engineers, 28 Victoria-street, London, S.W.1. (ABBey 6672.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Works Managers, 67-68 Chandos-place, London, W.C.2. (TEMple Bar 8324.)
Society of Instrument Technology, 20 Queen Anne-street, London, W.1. (LANgham 4251.)
Television Society, 164 Shaftesbury-avenue, London, W.C.2. (TEMple Bar 3330.)

BRITISH STANDARDS INSTITUTION

At the annual general meeting of the British Standards Institution, held in London on September 4, the two formerly separate offices of President and of chairman of the General Council were combined. Sir Herbert Manzoni, M.I.C.E., City Engineer, Birmingham, who is already chairman of Council, was elected the first President under this new arrangement. He succeeds Sir Roger Duncalfe, who has held all the principal offices in the Institution during the past 20 years. Mr. John Ryan was re-elected vice-president of the Institution.

Mr. P. L. Jones, M.C., M.I.C.E., a director of Swan, Hunter, and Wigham Richardson, Limited, Mr. G. L. Newman, secretary of the chief engineer's committee, Metropolitan-Vickers Electrical Company Limited, and Mr. B. E. A. Vigers, A.M.I.C.E., M.I.Chem.E., assistant managing director, Laporte Industries Limited, have been elected to be representatives of the Institution's Engineering Divisional Council to serve on the General Council.

The representatives of the Institution's Building Division elected to serve on the General Council are: Mr. H. A. Fursey, sales director of Turners Asbestos Cement Co. Ltd.; Mr. J. C. Tait, F.R.I.C.S., senior quantity surveyor of the Department of Health for Scotland; and Lt. Col. E. Vigor, managing director of the Neuchatel Asphalte Co. Ltd.

THE HUMAN ELEMENT

T.U.C. views on automatic production—Brake on wage demands officially abandoned—Attraction of women to home duties—United Nations convention to extend women's rights and limit slavery—Trade unionists answer a Gallup poll—Science teachers taken for military duties.

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Toleration for Automation

One of the most worthwhile debates at this year's annual conference of the T.U.C. was that on automation. The resolution finally adopted favoured automation, subject to adequate safeguards being provided for employees in respect of training in alternative employment and compensation for displacement. The main line of division in the debate was between those who dislike automation, but realise that they will have to come to terms with it, and those who actively support its introduction.

It is very noticeable, however, when organised labour discusses this subject, how all roads lead to Rome. In the T.U.C. debate, many of those favouring automation wanted a form of national planning to bring it about; a move which the General Council resisted and which, on a vote, failed to gain approval. The argument put forward was that only by planning could automation get through to the smaller concerns since, under a free-enterprise system, the larger companies would get in first and smother the smaller firms before they could put up an effective fight. When compensation for redundancy was discussed, Mr. Arthur Horner referred to the redundancy scheme which the miners had been able to obtain at the expense of a nationalised industry and told engineering employees they ought to make certain of doing as well out of private enterprise. There was clearly a thread running through all this argument which points to a basic assumption in many minds, namely, that automation is better handled under State planning because such a course increases workers' bargaining power on the terms of its introduction. On these grounds, the State control of automation is obviously desirable from the point of view of organised labour, but it is difficult to see what planning by the State can do for the smaller businesses. If nationalisation and State planning has achieved anything, so far as organisation is concerned, it is to extoll the virtues of bigness. The howlers which a central planning board might commit in estimating the market for mass-produced goods, on the basis of remote-control techniques, can be readily imagined.

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Restrained Unrestraint ?

Some little time must elapse before the significance of the decision of the annual meeting of the Trades Union Congress officially to jettison wage restraint is apparent. The decision was expected, and some of the larger unions had already embarked on a policy of " unrestraint " before the meeting at Brighton.

It is by no means certain that the emergence of a more militant attitude, apparent for some time in the Transport and General Workers Union, has caused as big a swing to the left, or as much discomforture of the old guard at the T.U.C., as is being generally assumed. Mr. Frank Cousins, general secretary of the T. & G.W.U., has had a heady diet of popularity at Brighton, but it remains to be seen how he reacts to power. The trade-union movement has tamed hotheads before. The newly-elected President of the T.U.C., Sir Thomas Williamson, has already said that he does not think that Congress will indulge in a wages scramble.

Meanwhile, however, the seriousness of the decision at Brighton must not be under-estimated. It is clear that there is a body of opinion in the trade-union movement which dislikes the present Government's economic policy sufficiently to accept a wages policy which would make it impractical and cause a change of Government. The most uninhibited yell at Brighton came when Mr. Cousins said that the workers wanted a socialist Government. The T.U.C. decision on wage restraint comes at a moment when there already exists powerful pressure to withstand deflation. Several unions are bent on pressing for higher wages and the T.U.C. will be more reluctant than before (which is saying quite a lot) to interfere in wage disputes, although it has recently been authorised to do so by its members. But the cooler heads on the General Council can still wield a great deal of influence behind closed doors.

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Emancipation in Reverse

Fifty years ago, the emancipation of women was discussed in terms of both political and economic freedom, but, in the event, political freedom has been conceded in most countries before economic freedom. Nevertheless, over the years, the right of women to earn an independent income has gradually become an obligation and a necessity in many countries as well as a right. In Russia, emancipation has meant just such an obligation. The housewife there has been a lesser mortal than her sister in the factory. Recently, the idea of such extremes of emancipation, if such it can be called, have been challenged by the statistics of broken homes and vagrant children, and the housewife may yet be upgraded by the dialectical materialists.

The same social problem exists in Britain, where the simple prejudice that children are better raised in a home in which home-making is a full-time occupation for the mother is being re-discovered. The lack of domestic servants, coupled with the development of labour-saving devices, is bringing added prestige to housework and the running of the home. The illusion that any woman can run a home but that it takes courage and imagination to work a typewriter is about due to be exposed. The illusion has behind it, however, a good deal of stern economic necessity in some parts of the country, as, for instance, in Lancashire, where women working in the mill is an old-established custom. In recent years, too, the rise in the cost of living has forced many married women to take up employment the country over. On the top of this has come awkward hours and, sometimes, bad working conditions. Again, many women have got used to spending an income and enjoying a standard of living which only a double income can support. In spite of these trends, it will be surprising if the current growing dislike on all sides of overtime working for so many men in industry does not begin a movement for putting more women back into the home.

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Is Slavery Receding ?

Variations in the degree of recognition of human rights throughout the world are as wide as those in the standard of living. It is important for highly-industrialised nations to realise that the trade in human beings and their labour is still active in some parts of the world, and that high-flown metaphors about the slavery of the worker have a grim literal interpretation.

Last week, a convention dealing with the rights of women and the slave trade was signed by 40 States at the United Nations. Signatory countries agreed that certain of the cruder forms of trade in human chattels should become a criminal offence under their own legal codes, and it is worth recording that the practice of branding is still prevalent enough in some places to warrant a specific article in the convention.

It had been thought that Saudi Arabia might resist the convention at the last moment and might find supporters who would shelter behind its initiative but, in the end, there was no country against the convention, and only three abstentions. How many countries actually signed the convention in spirit, as opposed to those giving it mere lip service, remains to be seen. How many will implement what they have signed is even more problematical. In any case, these matters are slow to make progress, for custom as well as the market, is in favour of the established institution and against innovation.

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Better Working Conditions Wanted

There is always a danger that public opinion polls will put answers into people's mouths by asking simple categorical questions, or that the questions will be misunderstood. Yet these polls serve a purpose on topics of the day, by getting a response from a mass of people who are not normally articulate. Last week the *News Chronicle* printed a Gallup Poll taken from among union members, and the answers to the questions asked were not quite what was expected.

In order of priority, the matters on which union members laid greatest emphasis were better working conditions, better pension schemes, long-term contracts, higher wages, profit-sharing schemes, compensation for dismissal, and a share in management. Higher wages, it will be noticed, came comparatively low on the list and after long-term contracts. Better conditions of work and better security, on the other hand, were placed first.

A recent survey among workers, mentioned in these columns (ENGINEERING, July 20, page 96) also emphasised the importance of pensions and it is of particular interest that security still looms so large in the thinking of operatives. (In our previous survey there was admittedly a large element of clerical employees). It would almost seem that the British worker has taken to heart the example of his opposite number in the United States, where long-term contracts are becoming increasingly fashionable. It leads to the thought that the unions in this country might well accomplish more for their members if they pressed for long-term contracts in negotiations, and encouraged thrift campaigns among their members. This country can take high and stable wages if consumption is curbed.

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Calling-up Teachers

The sea claims its own. So, too, does the War Office—though it might not like the metaphor, drawn from across the way at the Admiralty. The partial call-up for the Suez crisis has fallen particularly on technical men. Beyond agreeing that this course is probably quite right, common sense and administrative convenience appear to part company.

One of the country's most precious commodities at the moment is its slender supply of science teachers in schools. On their number and quality depends the flow of an adequate supply of technicians and professionally-trained men in the next generation. Yet it seems that, at a time when this problem is at its most acute stage, and organs of public opinion are drawing repeated attention to the shortage of good science teachers, partial mobilisation has made off with a sizeable number of them.

The swoop appears to be no very short-term affair either. Even if the crisis is shortly resolved, or soon enters a less acute phase, the mobilised teachers will not be rushed back for the start of the new term which is now opening. They will be kept for some time; probably for a month or two. Basically, the War Office is right to take technical men under the present emergency, but there should have been some discrimination in their choice, and when the emergency passes the men concerned should be returned as quickly as possible to civilian life. It was never truer than today that battles are won on the playing fields of Eton and the teachers are wanted on those fields at the double.